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APPLICATION OF A THREE-DIMENSIONAL WATER QUALITY MODEL TO THE JAMES ESTUARY

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APPROVAL SHEET

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ABSTRACT

Water quality models continue to increase in options and accuracy as super computer access becomes a reality for water quality management. The US Army Corps of Engineers (USACE) Waterways Experiment Station (WES), in Vicksburg, Mississippi has developed a state of the art modeling framework for simulating the hydrodynamics and water quality standards of the Chesapeake Bay. As environmental engineers focus more attention on Bays tributaries this year, this complicated model must be accurately applied to the major freshwater rivers emptying into the Bay.

To discover the feasibility of applying the models to a smaller estuary system, the Chesapeake Bay model was reconfigured and applied to the James River Estuary in Virginia. The alteration mandated input file data reconstruction and development, basin mapping, and site specific code adjustments for the models and the post-processor. The model size and memory needs dictate super computer enrollment for accurate and timely system utilization. The model was calibrated using salinity data on the James Estuary, and verified by dissolved oxygen and chlorophyll *a* responses to nutrient loadings. A model sensitivity analysis of the results was conducted to ensure that reliable results were obtained.

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1. INTRODUCTION

In recent years, considerable research has centered on the contamination and pollution of the large estuary systems of the United States. One prominent example, is the concern for the declining water quality of the Chesapeake Bay. In 1983, the U.S. Environmental Protection Agency (USEPA), published study reports (USEPA 1983a, 1983b) outlining the major influences on degrading water quality in the Chesapeake Bay. The study revealed that inputs of nutrients and toxicants from point and non-point sources, changes in land use within the basin, and natural events, floods and droughts, combined to foul the estuary system.

To coordinate clean-up efforts and provide a management structure, the Chesapeake Bay Program (CBP) headed the project. The Program's charter was to organize federal, state and private efforts to restore the Bay. In order to effectively and fiscally manage the operation, the CBP relied on a number of tools to assist in planning, implementing, and evaluating recovery strategies. Among these tools was a three-dimensional (3D), time-varying water quality model of the Bay and its tributaries completed by the Army Engineers Waterways Experiment Station (WES) in 1992. The modeling framework allows engineers and researchers to test proposed management and conservation actions on a computer simulation of the entire Chesapeake Bay watershed to determine their overall effects on the estuarine ecosystem. This process provided the CBP with realistic and cost-effective strategies

for improving the aquatic quality of the environment in the Chesapeake Bay.

Recently, the CBP's governing body, the Chesapeake Bay Executive Council has mandated (Virginia Chesapeake Bay Program April, 1993) the states of Virginia, Maryland, Pennsylvania, and the District of Columbia, with support from the U.S. Environmental Protection Agency (EPA), to develop customized "tributary strategies" for each of the Bay's river systems.

The purpose of the tributary strategies is to reduce the excess nutrients, nitrogen and phosphorus, that rob the Bay system of life giving oxygen. The strategies call for each state to evaluate its rivers' nutrient problems and to adapt a package of solutions for each river basin. Virginia will be required to develop a nutrient reduction strategy for three major basins: the James, York, and Rappahannock rivers.

The tributary strategies development process in Virginia will take place over several years and in two distinct phases. In the first phase, between now and August 1993, Virginia will develop interim strategies aimed at reducing nutrients by 40 percent by the year 2000. This is the same goal that was set for the Bay in the 1987 Chesapeake Bay Agreement. The second phase, from August 1993 to 1997, will focus on development of more precise long-term nutrient reduction goals for each river. To arrive at more precise numerical goals, Virginia will be working with the EPA to conduct additional water quality monitoring and modeling.

To assist the state in constructing a precise strategy for each river basin, the three-dimensional water quality model, used to support engineers and planners on the Bays clean-up, must be reconfigured and adopted to each Virginia watershed.

The information generated by the models would be invaluable to any potential tributary strategy. For example, as modelers and environmentalists determine the long term fate for a tributary basin underwater plant and animal life must be modeled. To accurately simulate this data the complex lateral dispersion in an estuary must be considered. A three dimensional water quality model simulates this dispersion and could provide the planners accurate information on the aquatic response to test strategies.

Additionally, the model would allow planners to foresee what the consequences of each potential strategy would be in terms of nutrient reduction in the entire river ecosystem. This process would allow the state to select the best course of action for each basin at the lowest cost. Application of the Chesapeake Bay modeling framework to a smaller, *tributary size system*, is the purpose of this research. Reconfiguring the framework and adopting it to the tributary systems and obtaining credible results is the goal.

2. THE CHESAPEAKE BAY WATER QUALITY MODEL

The Chesapeake Bay is the United States largest and most productive estuary. It consists of the main Bay, with a watershed of over 64,000 square-miles, five major western-shore tributaries, and a host of lesser tributaries and embayments. The mainstream is roughly 300 km long 8 to 48 km wide, with an 8 m average depth. The primary sources of freshwater to the system are the Susquehanna River (62% of total freshwater flow), the Potomac River (18%) and the James River (11%). The Bay is a partially-mixed estuary in which long-term circulation is upstream along the bottom and downstream flow is situated near the surface.

The model of the Chesapeake Bay was developed by the U.S. Army Corps of Engineers (USACE) Waterways Experiment Station (WES). The modeling framework consists of four different modules coupled together to provide the user with functional data about all aspects of the water column. The four models developed are: 3D curvilinear hydrodynamic model (CH3D) (Johnson *et al*, 1991), a water quality model (CE-WQM) (Cerco *et al*, 1992), a sediment oxygen demand and nutrient flux model (HydroQual, 1989), and an indirect coupler (Dortch, 1990) which preserves transport characteristics of the hydrodynamic model in the water quality model.

The models were designed and coded to operate primarily on the Chesapeake Bay. WES is currently applying the system to the Delaware Bay and River Estuary located between Delaware and New Jersey; however, the models have not yet been applied at a reduced physical scale to a tributary estuary . To test the models at these

conditions, the James River Estuary in Virginia was selected as a simulation basin. This estuary was ideal because it has readily available data about its hydrology and water quality standards over a diversified range. Additionally, the James River Estuary is a medium size tributary with above average nutrient loads. Applying the model to this river would accurately forecast future tributary uses for the WES modeling framework.

Application of the model to the James River would require converting the grid pattern of the Bay to a suitable formation for the Estuary. The original model of the Bay used a grid resolution of 1.52 m vertical, 10 km longitudal and 3 km lateral, to accurately capture the hydrodynamic processes of the Chesapeake (see Figure 2.1), and still contain few enough boxes to compute results in a reasonable time.

This scale produced 734 active horizontal cells spread over a maximum of 15 vertical layers, resulting in 3992 computational cells. This resolution allows major tributaries to be modeled at fully 3D in the lower reaches. In the upper reaches; however, the scale produces constant-depth, 2D flow. This scaling level is appropriate for modeling water quality issues confronting a large body of water like the Bay. This scale however, makes it difficult to accurately simulate hydrodynamic flow, and more importantly, contamination and pollution tendencies on the Bay's major tributaries. The James River above the mouth of the Chickahominy River varies in width from 100 to 1100 m. This reach in the WES model is scaled at the minimum box width of 3 km and modeled as depth-averaged flow. This considerable size difference makes water quality computations

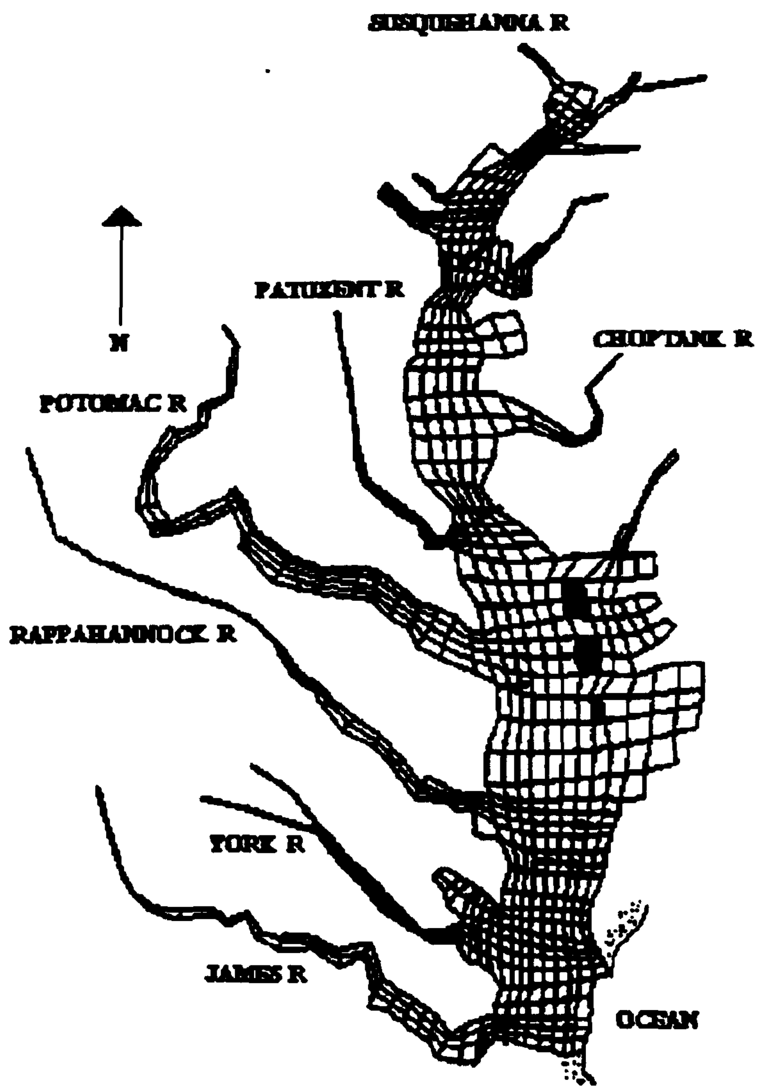


Figure 2.1 Physical Grid of Chesapeake Bay

unreliable. To apply the model to tributaries, the scale and resolution of the grid must be altered to accurately represent the flow field of the rivers.

In addition to converting the grid scale, transformation of the model to the James River Estuary will require several other major overhauls. Reorienting all flow faces and boxes in the new scaled model will be imposed. Additionally, all time-varying data and model rates and constants must be altered to imitate the new region. Finally, site specific computer codes must be removed or updated in the programs to ensure the model correctly corresponds to the James River Estuary.

3. RESEARCH OBJECTIVES

The basic hypothesis for this research is that the WES models could be reconfigured and applied to smaller estuaries and rivers and accurate modeling could be achieved. The goal of this research is to apply the WES models to the James River Estuary and attain credible results. The primary emphasis of the investigation is to fully develop the water quality model with secondary priority on the hydrodynamic system. The following objectives have been established to accomplish this goal:

1. Obtain all four models from WES through close coordination with the United States Army Corps of Engineer District , Baltimore (USACEB). The models are restricted, and USACEB will have to grant approval for technology transfer.

2. Map the James River estuary and develop input files for the models. Input files will require river bathology, inflows, wind diagrams, tidal charts, temperature fields, Mannings n, and salinity.

3. Utilize the RS-6000 computer and UNIX and JOVE to edit and compile the programs.

4. Alter the hydrodynamic model to a simulated James River box model, with a reduced resolution.

5. Develop a water quality model that corresponds to the hydrodynamic box model of the James River.

6. Utilize the coupler to link together output from the hydrodynamic model to the water quality model.

7. Produce results that closely model data that has been collected on the James River.

4. DESCRIPTION OF STUDY AREA

4.1 The James River Estuary

The James River is the southernmost of the major rivers emptying into the Chesapeake Bay. It extends the entire breadth of the state of Virginia from its mouth at Hampton Roads to its headwaters in the Appalachian Mountains near the Virginia-West Virginia border. The James River basin is the largest basin in Virginia, incorporating just over one-fourth of the states total land area and all or part of 39 counties and 18 cities. The major industrial complexes along the River are Newport News, Hopewell, Richmond, and Lynchburg.

The tidal or estuary portion of the James River (see figure 4.1), extends 105 miles from the mouth of the River to approximately Richmond. Associated with this section is 3600 square miles of drainage area. Industry in the tidal basin varies. In the Richmond-Hopewell-Petersburg area, heavy chemicals, tobacco products, food products, synthetic fibers and paper, plus agriculture and lumbering provide the bulk of the commerce for the area. The lower tidewater area of Newport News-Hampton-Virginia Beach is dominated by meat and chemical processing, port activities, military complexes, and space research.

As industry and population increase in the James River basin, so does pollution and contamination in the water column. The by-product of development is discarded by both communities and industry into the Estuary for removal to the

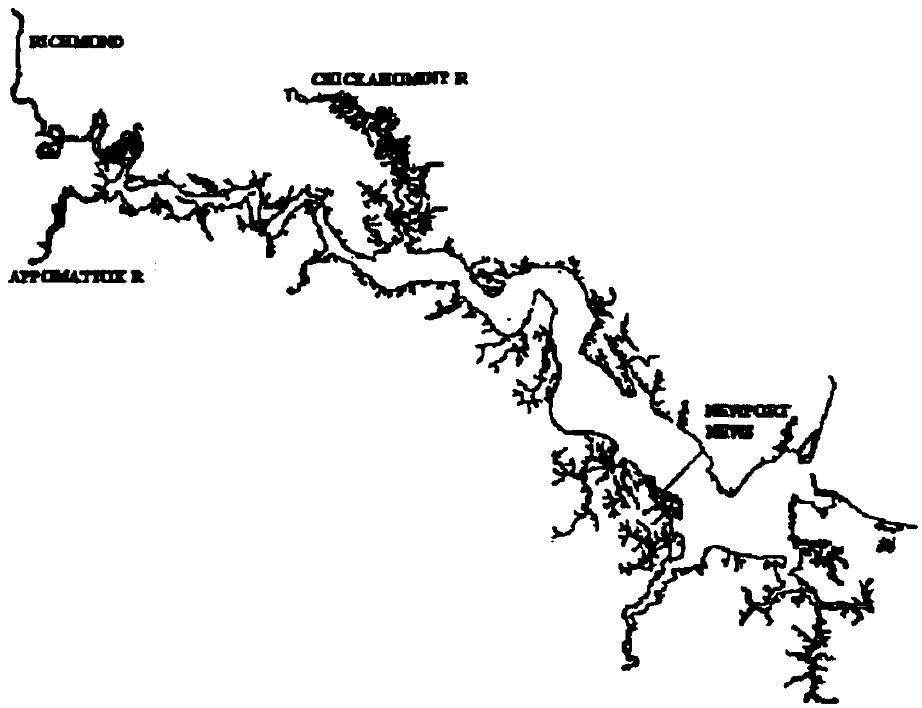


Figure 4.1 James River Estuary

Atlantic Ocean. The growth has meant jobs and economic success for the region, however, water and sediment standards in the Estuary have been eroding at a fast pace. Regulatory standards issued by the EPA have dictated outfall tolerances, and improvement of the water and sediment quality in the region is mandatory.

The water quality impacts cannot be successfully assessed without a modeling framework that accurately depicts the hydrodynamic motions of the estuary and simulates water and sediment responses to both point and non-point source actions. WES has developed a complex modeling system that accurately depicts responses to loadings in the Chesapeake Bay. This same modeling framework could be applied to the James River Estuary if the resolution of the models are reduced, and input files are altered to depict the current hydrodynamic and water standards of the Estuary.

4.2 Water Quality Data and Information to Support Modeling Analysis

Data on the water quality of the James River Estuary will be constructed through the compilation of multiple sources. The major proponent of field data is WES (Cerco, 1992). This reference contains the major point and nonpoint sources loads entering the James River Estuary. Additionally, the document depicts atmospheric loadings, and tables all the rates, constants and parameters used by WES in their experiments on the Chesapeake Bay. The U.S. Geological Survey will be utilized for snapshot pollutant concentration along the Estuary. This data will be used to verify the results of the model after calibration. Discrepancies in the mass or

concentration of pollutants will be referred to the VIMS manual "Water Quality in Chesapeake Bay, Virginia Portion". This manual covers pollutant loadings for the water year 1989, and the model will simulate 1986 data, however, the data provides a range for verifying results and depicts the general shape of concentration versus time curves.

The boundary and initial conditions for the water quality model will be acquired from the U.S.G.S. The meteorological data required by the model, light extinction coefficient and temperature, will be obtained from the National Ocean and Atmospheric Administration (NOAA).

The data required for the hydrological model will mainly come from the Department of Commerce. NOAA will produce the daily tidal information, the wind speed and direction, the ambient temperature, the basin bathology, and the initial water salinity. Daily flow volumes and water temperatures will be received from the USGS. Grid transformation of the basin to an acceptable coordinate system will be accomplished with WESCORA (Thompson, 1983) a grid generation program received from WES.

5. WATER QUALITY MODEL

5.1 Basic Theory and Formulation

The water quality model (Cerco *et al.*,1992) is based on the integrated compartment method (ICM). The ICM or box model approach is based on the mass conservation equation for an infinitesimal point into a finite control volume from which it was originally derived. Using the integral theorems of vectors and replacing integrals over surfaces with summations over compartments faces, the following mass balance equation is derived:

$$\frac{\delta V_i C_i}{\delta t} = \sum_{j=1}^{n} Q_j C_j + \sum_{j=1}^{n} A_j D_j \frac{\delta C}{\delta x_j} + \sum S_i$$

where:

V_i = volume of ith compartment

C_i = concentration in ith compartment

Q_j = volumetric flow across flow face j of ith compartment

C_j = concentration in flow across flow face j

A_j = area of flow face j

D_j = diffusion coefficient at flow face j

n = number of flow faces attached to ith compartment

S_i = external loads, kinetic sources and sinks in ith compartment

t, x = temporal and spatial coordinates

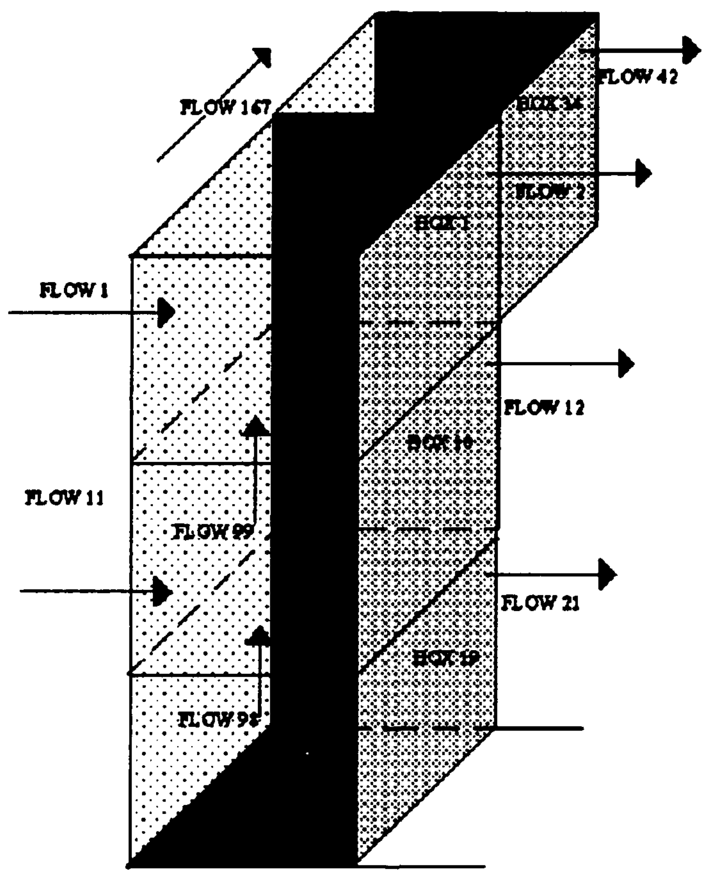


Figure 5.1 Box Model

The water quality model simulation area is segmented into compartments, subsequently, the mass balance equation is applied to each flow face for each constituent. In order to map and generate a naming sequence, each box and flow face is numbered in all dimensions. A three-dimensional example of a numbering follows in Figure 5.3

The four basic cycles simulated by the water quality model are carbon, nitrogen, phosphorus, and silica. Each of these compound systems are applied to the mass balance equation to ascertain where the production and decomposition of each product is occurring. In the carbon cycle (see Figure 5.2) three state variables are considered: dissolved organic carbon (DOC), labile particulate organic carbon (LPOC), and refractory particulate organic carbon (RPOC).

In the nitrogen cycle (Figure 5.3), the nitrogen is divided into an organic and mineral fraction. Organic nitrogen state variables are: dissolved organic nitrogen (DON), labile particulate organic nitrogen (LPON), and refractory particulate organic nitrogen (RPON). Two mineral nitrogen forms are considered by the model: ammonium (NH_4) and nitrate (NO_3).

As with carbon and nitrogen, the organic phosphorus cycle (Figure 5.4) considers three compound fractions: dissolved organic (DOP), labile particulate (LPOC), and refractory particulate (RPOP). Only a single mineral form, total phosphate (PO_4), is contemplated.

The silica cycle (Figure 5.5) is grouped into two variables : available silica

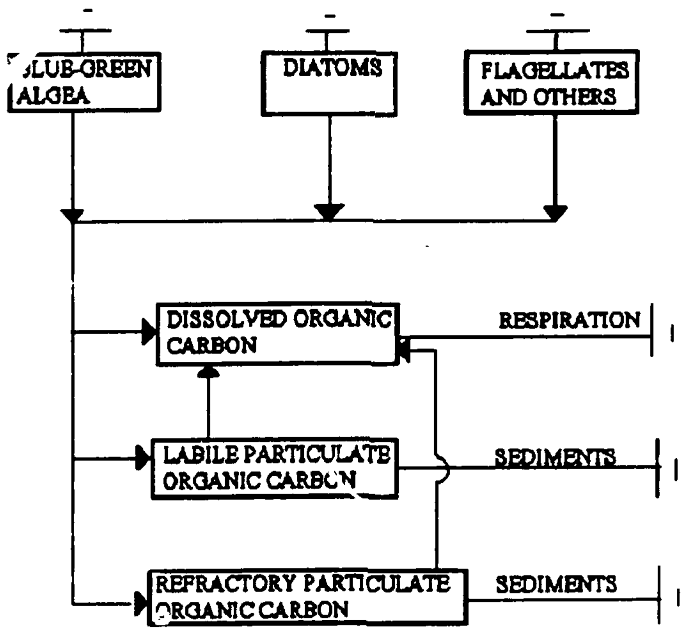


Figure 5.2 Carbon Cycle

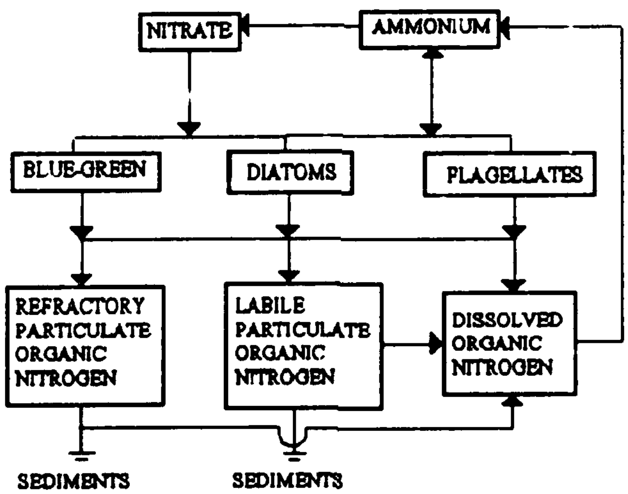


Figure 5.3 Nitrogen Cycle

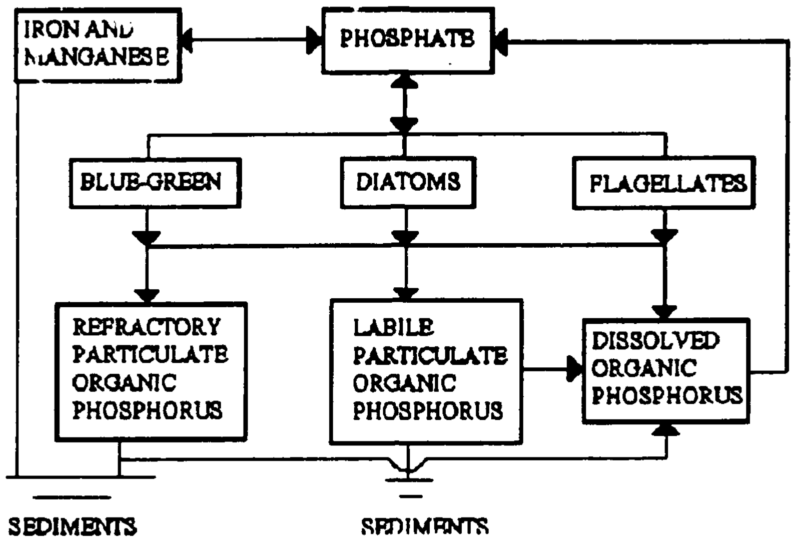


Figure 5.4 Phosphorus Cycle

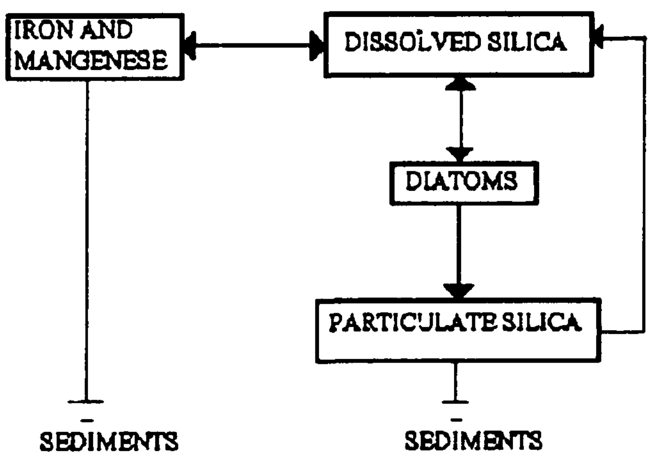


Figure 5.5 Silica Cycle

(SA) and particulate biogenic silica (SU). Available silica primarily dissolved and can be utilized by diatoms while particulate biogenic silica is of no value to plant life. In addition, the water quality model also considers the following 5 state variables in its simulation of an estuary:

TEMPERATURE - is the primary determinant of biochemical reactions.

TOTAL ACTIVE METALS- is defined as the total concentration of metals that are active in phosphate and silica kinetics. Total active metal is partitioned between particulate and dissolved phases by an oxygen-demand partition coefficient.

CHEMICAL OXYGEN DEMAND - is the concentration of reduced substances that are oxidized by inorganic means.

SALINITY - is a conservative tracer that allows for verification of the transport component of the model and facilitates examination of conservation of mass.

DISSOLVED OXYGEN - is the central component of the water quality model. The availability of DO determines the distribution of organisms and the flows of energy and nutrients in an ecosystem.

5.2 Input File Development

The Waterways Experiment Stations (WES) water quality model consists of a main model and 21 subroutines. The main model's basic purpose is to read variables and recycle the design sequence of the simulation calling on a series of subroutines to accomplish repetitive tasks. The main models initial mission is to open all 13 input files and create the framework of desired arrays for the package to execute the program. Simultaneously the code requires the model to initialize all computational variables for the simulation period. During this stage, logic control switches are turned on and off, the basic geometry is input to the model, and positive and negative flow is decided for the geometric setup of the simulated region.

The actual simulation process begins after the preparation stages of the model have been completed. The model cycle begins with boundary condition and flow updates, determined from subroutines, assigned to each face in the model. Once satisfied, the mass or concentration of each constituent being simulated is designated for each box in the model. The simulation system then updates the lateral, longitudal, and vertical transportation schemes of each face. The cycle then revises the concentration or mass of all components in each model box and the cycle is complete.

The subroutines contained in the model are:

1. HYDRO - inputs the hydrodynamic flow file to the water quality model and continually updates the flow information for the model.
2. TVDS - computes the time-varying data updates required by the model.

3. AVERAGES - determines average flux and plot information for the simulation.

4. KINETICS - conducts the required computations for each constituent in the model. The subroutine has a kinetic and kinetic flux routine for each of the following parameters:

1. water temperature
2. suspended solids
3. algal species
4. carbon components
5. nitrogen components
6. phosphorus components
7. chemical oxygen demand
8. dissolved oxygen
9. silica components
10. benthic flux

Prior to developing the model input files, setup parameters in the common file must be altered to coincide with the configuration of the model test region. The numbers are used by the model to set array sizes and determine the number of simulated boxes and faces. Appendix A is the common file with the required data for the James River Estuary. The input framework for the water quality model consists of a basic control file and 13 optional input files representing various parameters and

loading standards for possible simulation. Output is dispatched into 10 possible files selected from the basic control file. A brief description of each input file and the source of data for the James River Estuary follows:

1. The basic control file for the water quality model is seen in Appendix B. The file contains the parameters used to run and control the model. The file details timestep information, input and output file descriptions, on and off switches for model features, and variables and constants required to execute the program.

2. The Map File specifies the linkage between faces and boxes in the model. To construct the file, every face and box in the model is assigned a sequential number. The faces are denoted in either the X or Y direction first, and then applied to the vertical faces. Once each face has been numbered, it is allocated a position by relating the location of the face to the boxes that surround it. Additionally, a code is applied to each face to represent its primary flow direction. The Map File also contains the number of vertical faces in each column, the bottom box number in each column, and the vertical face numbers in the column starting from the bottom. Appendix C is the map file for the James River Estuary. The map contains 68 boxes and 149 faces in a three-dimensional array.

3. The Geometry File is used to specify the box dimensions , volumes, and water column depths in each box. Additionally, the file contains the surface and benthic box number for each column created by the mapping system. Appendix

D displays the James River Estuary geometric interpretation. The file relays box sizes of 17.5 km longitudally, 1.5 km latitudally, 2 meters in depth, and a volume of 5.25×10^7 m^3. The file strings for each box also contain the depth of the surface of each box and the upper box number for orientation purposes.

4. The Initial Conditions File denotes the starting concentration for the model and any box specific modifications to initial conditions for a specific portion of the simulation. Appendix E is a duplication of the James River Estuary input file. The file begins with the day 1 concentrations of all twenty-two state variables for the Estuary, and the seventeen initial variables for the sediment model. The model assigns every box in the geometric file the initial condition specified. If a box requires a higher or lower initial concentration, modifications are made following the original input sets.

5. The Algae Growth Rate File contains the spatially-varying algae growth rates for each box in the grid. Algae is subdivided into three components cyanobacteria, diatoms, and green algae, and each rate is determined for each box in the model. Appendix F is a sample of the James River Estuary input rate.

6. The Settling Velocity File specifies the spatially-varying water column settling velocities for the simulation. The input file contains seven velocities for settling speeds of different compounds and particles over the entire region. Appendix G notes the velocities for a portion of the James River Estuary.

7. The Meteorologic File inputs the weather conditions in the simulation region. The coefficient of surface heat, equilibrium temperature, daily

illumination, and fractional day length are all contained in the file. Appendix H is a portion of the collected data for the James River Estuary.

8. The Point Source Loads File contains the time-varying point source loads to the Estuary. The initial card contains all 22 state variables and the number of times each constituent is loaded into the Estuary. The next series is the box number of where the loading occurs, followed by the julian date and the load in Kg/day to the system. Appendix J is the point source loads placed in the James River Estuary during the simulation cycle.

9. The Nonpoint Source Loading File (appendix K) is structured in the same fashion as the point source file, the only difference is that this file accounts for nonpoint source pollution loads to the ecosystem.

10. The Atmospheric Loading File contains the atmospheric loading of nitrogen and phosphorous based pollutants. The file, see appendix L, is structured with the julian date followed by the average rainfall and then ammonia, nitrate, dissolved organic nitrogen, phosphate, and dissolved organic phosphorus loadings from airborne sources.

11. Space and time varying light extinction coefficients are condensed in the Light Extinction File. The data file, appendix M, is constructed with a Julian date followed by a field of light extinction values corresponding to the number of boxes.

12. The Constituent Boundary Concentration File contains the time-varying boundary concentrations for all of the constituents at each boundary face.

The file is structured with a state variable listing of the number of boundary conditions occurring in the simulation. As appendix N denotes, the next card contains the julian date followed by the constituent concentration of each boundary box, placed in ascending box number order. The Alpha line allows the modeler to increase or decrease the concentrations to the whole system by fractioning the loading.

13. The Hydrodynamic File is the field flow data generated for operating the water quality model. The data can vary from depth averaged 2 dimensional information to unformatted output files constructed from a running CH3D over a similar time period and region. The type of input file: formatted, unformatted, 2-dimensional, is read from the basic control file. The Hydrodynamic File, see Appendix P, contains the flow information required for use in the water quality model. The data setup also relays the area and a flow and diffusion coefficient per face.

6. APPLICATION TO THE JAMES RIVER ESTUARY

6.1 Model Segmentation

The James River Estuary Basin was modeled in the 68 box, 149 face configuration shown in Figure 6.1. This modeling schematic was selected to ensure full vertical mixing and to develop a partially-mixed estuary in which long-term

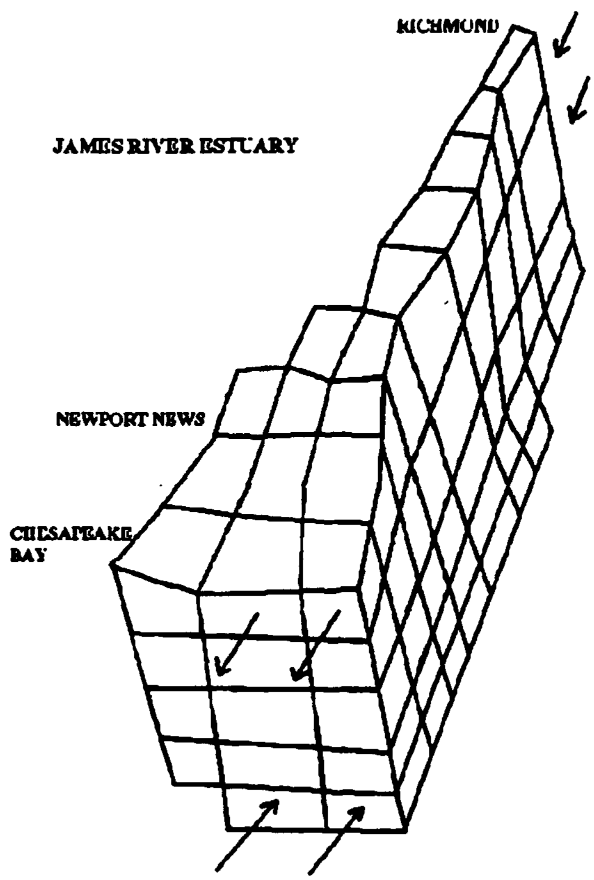


Figure 6.1 James River Estuary Model

average circulation is upstream along the bottom and downstream near the surface. The box model initially contained over 300 cells and 1000 faces. However, as the cells and faces were mapped in three-dimensions, for both the water quality and hydrodynamic models, locating and numbering became an arduous task.

To run CH3D, a grid generation program WESCORA, first had to be developed. This mapping system is a series of slits and slabs which relay to the computer positions and locations. This program contains a series of input files detailing corner, box, and face locations. The greater the number of boxes and faces, the larger and more detailed the input files became. In order to acquire greater detail, by increasing the number of cells, larger more unreliable input files were created.

The water quality model mapping system requires that every face and box be numbered and located with respect to all surrounding boxes. In a three dimensional model, this numbering system can quickly get out of hand. This project attempted to reduce the resolution of the model to more accurately simulate tributary flows. Numbering and accounting for boxes on that scale, without computer assistance, is almost impossible. In order to number and account for every face, a physical drawing or sketch of the area is mandatory. A three dimensional plan diagram of an estuary with hundreds and thousands of boxes and faces becomes staggering. For this simulation, 68 boxes and 149 faces were used to describe the James River Estuary. This reduced in scale from the Chesapeake Bay model only the lateral dimension from 3 km. to 1.5 km. This mapping of the Estuary took almost two weeks to

correctly relay to the computer.

6.2 Mass Transport

In a three-dimensional model, as in all compartment models, mass must be conserved across all faces and throughout the entire ecosystem. To operate this model, flow data known at three boundary conditions, the Upper James, Chickahominy, and the Appomattox rivers was used to determine flows across all faces in the model. Appendix P contains the flow fields and corresponding flow faces. The data fits a classic estuary design, with brackish water slowly moving up the river bed, and the surface flow moving the fresher water downstream.

To verify the mass transport results salt, a conservative substance, was examined at the top and bottom levels of the Estuary throughout the entire range of the basin. The results (Figure 6.2) details salinity concentrations to be within acceptable limits throughout the test region.

6.3 Nutrient Loads

The James River Estuary supports a wide variety of living resources. These animals need the proper aquatic conditions to thrive. They particularly need oxygen to survive. Excess nutrients, nitrogen and phosphorus, have been over-fertilizing the Estuary for decades. This loading causes an overabundance of algae that prevents sunlight from reaching underwater plants. When the algae dies, the process of decay robs the water column of life giving oxygen.

Much of the nutrients that flow into the Estuary are natural. Excess nutrients to the system are contributed from sewage treatment plants, some industries, and

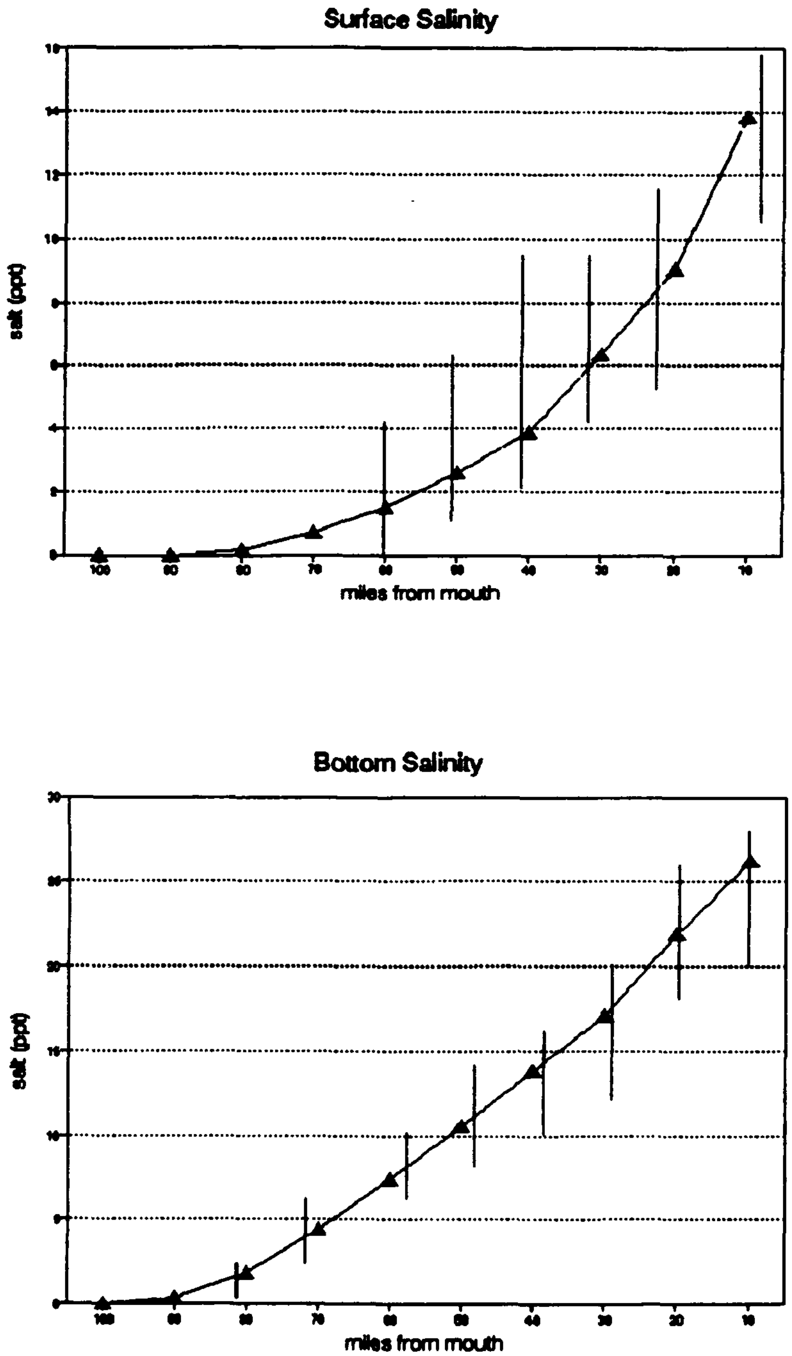


Figure 6.2 Salinity Results of the Model

farm and suburban lawn fertilizers. Nitrogen and phosphorus come from two main sources. One is "point source" pollution, which occurs primarily when sewage treatment plants and industrial facilities discharge treated wastewater into a river. The other is "nonpoint source" pollution, most of which is runoff from agriculture and developed areas. To model the James River Estuary, point and nonpoint source wasteloads were introduced into the ecosystem through the face in the model closest to the actual physical location of the sources. Additionally, the model contains the ambient or background concentrations of the desired constituents at all boundary conditions.

Output nutrients and conditions examined are: total nitrogen and phosphorus, dissolved inorganic phosphorus, ammonia, dissolved oxygen, and chlorophyll *a*. These six compounds will divulge nutrient loading and spreading throughout the Estuary, and predict the response of algae and the Rivers oxygen supply to the stimulus.

6.4 Water Quality Simulations

The water quality data collected and used for this simulation was provided by Dr. Carl Cerco of the Waterways Experiment Station (Cerco, 1992). The data represents a 90 day period from January through March of 1986. The statistics for this period consist of average inflow condition and normal pollutant loading for the region. The time step used for the water quality model was adjusted during the simulation to determine which span provided the most stable results. The model was executed at three different time steps, 6 and 9 minutes, and with autostep. All three

simulation produced similar results, so the autostepping option was selected for the final analysis. Autostepping automatically adjusts the time step to satisfy the horizontal flow stability restriction. It was developed by WES to take advantage of potentially larger time steps during low flow periods of simulation. Use of the feature can reduce run time, as fewer iterations of the model are required to produce accurate results. This feature will become extremely important as cell sizes are reduced to increase the models accuracy, and as run times become longer.

After verifying the models success with salt, it was calibrated with nutrients and dissolved oxygen. Figures 6.3 - 6.5 indicate the results of these simulations. All six inserts display clearly the nutrient loads acquired from the industry and POTW's in the Richmond area. These loads, however, begin to abate immediately as nitrification and phytoplankton begin to uptake the nutrients between Richmond and Hopewell, Virginia. This is verified as the staggered chlorophyll *a* diagram increases in a delayed manner and then diminishes as the nutrients decrease and the Estuary's size and depth expand.

The model calibrations reproduce the phytoplankton chlorophyll *a* very closely. The profile indicates a rapid growth of algae about twenty miles downstream of Richmond, with a peak as the Appomattox River empties into the Estuary at mile marker 70. The depreciation of growth over the remainder of the watershed is due to significant light limitations and increasing channel depths and widths below Hopewell. These influences cause an unfavorable condition for algae growth (Lung, 1985).

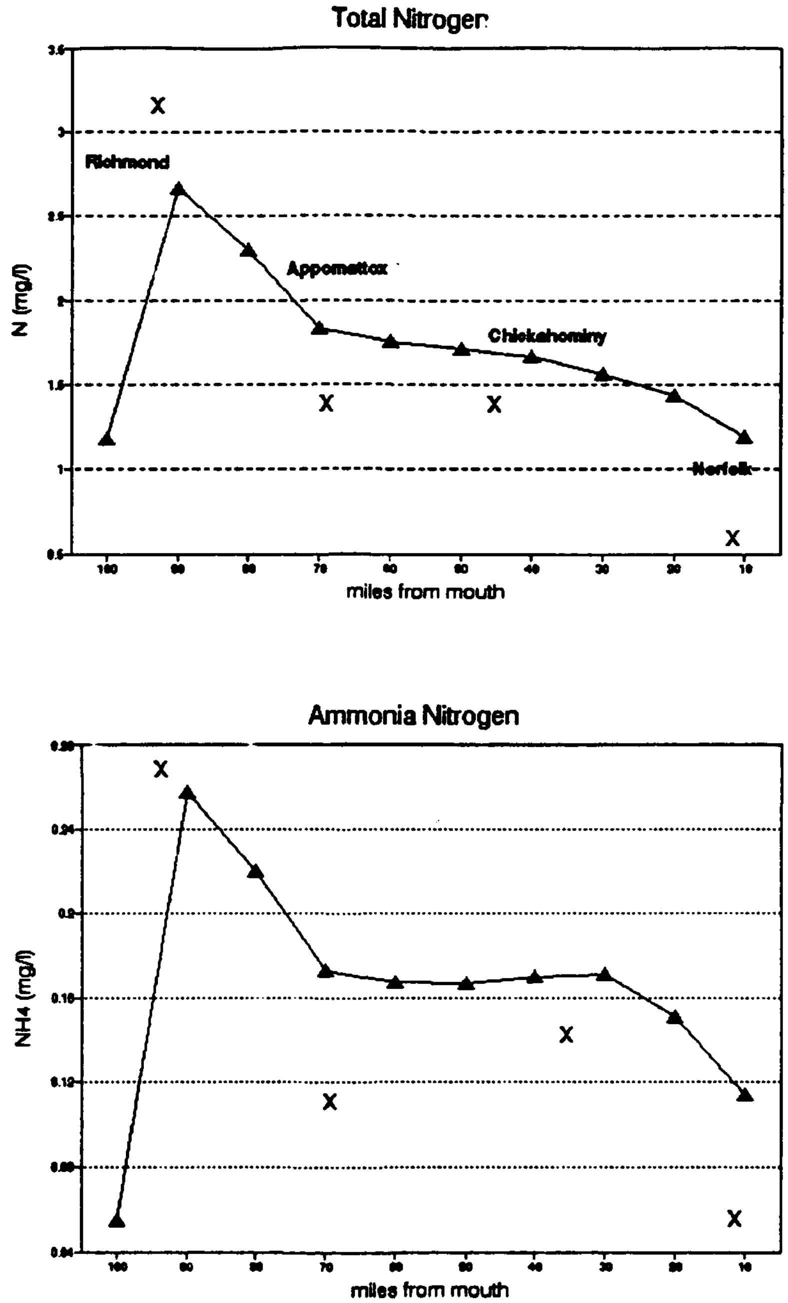
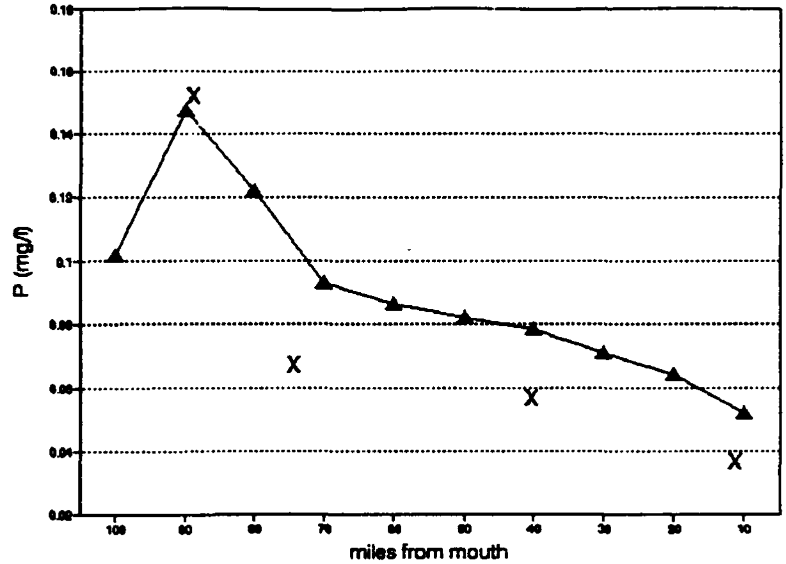


Figure 6.7 Nitrogen Model Results

Total Phosphorus



Dissolved Inorganic Phosphorus

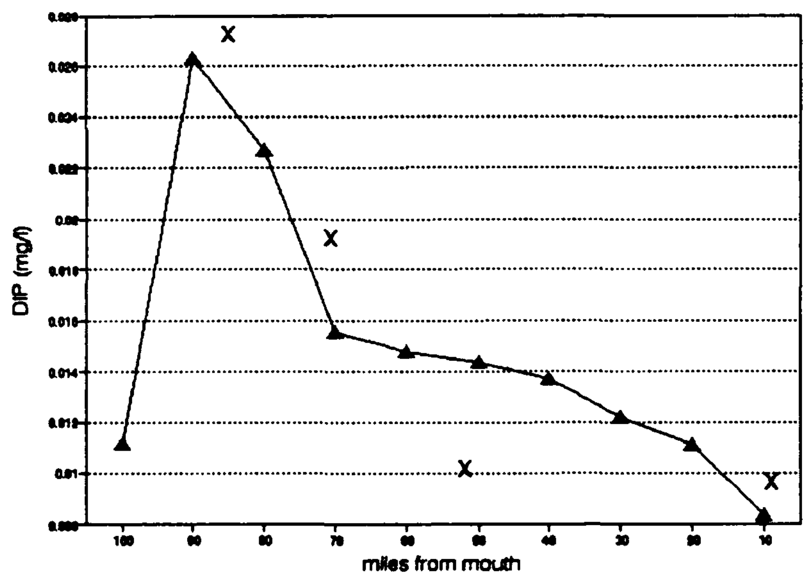
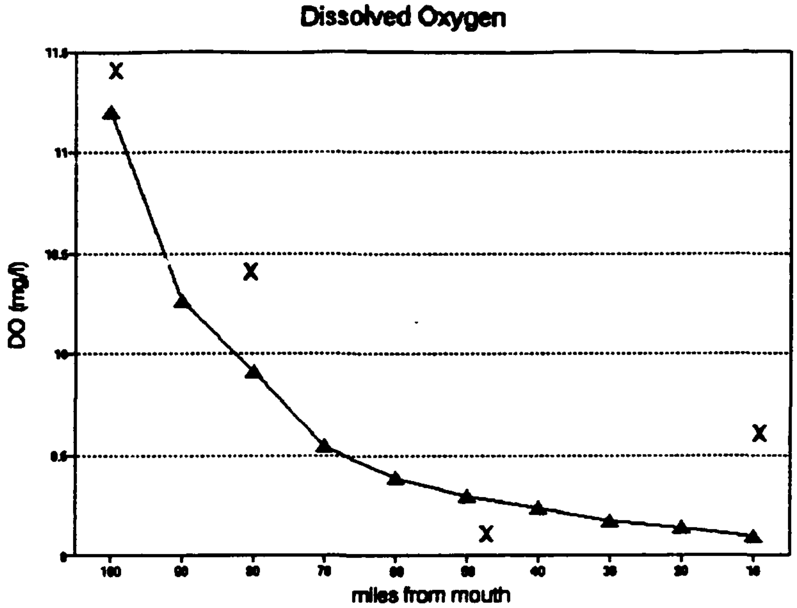


Figure 6.6 Phosphorus Model Results



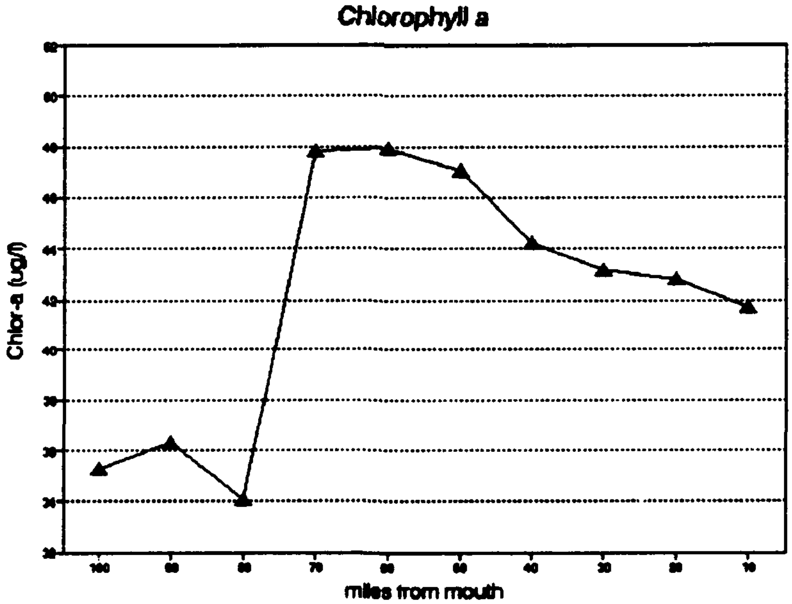


Figure 6.8 Dissolved Oxygen Model Results

All four nutrient load diagrams closely resemble each other. This fact suggests that point source discharges in the Richmond area are responsible for the sharp increase in nitrogen and phosphorus loading during the first 10 miles of simulation. Non point source loading would be distributed through the entire region producing a gradual increase in concentrations. Additionally, all four diagrams demonstrate nutrient abatement stalling around the mouth of the Appomattox River about 70 miles from the Chesapeake Bay. This hints that the POTW and point source loadings from the Appomattox River, and more directly Hopewell, Virginia, are substantial. All nutrients and the Estuaries dissolved oxygen begin to gradually return to ambient standards by 40 miles from the mouth. At this location, the turbidity and increased water volume create adverse growth conditions. These findings are in accordance with the Virginia Chesapeake Bay Program findings that 64% of the nitrogen loading into the James River Estuary is from point sources. The watershed is dominated by large industrial centers, which control the loading scheme.

The dissolved oxygen profile determines the fate of the aquatic life in the Estuary. Its depression below Richmond is due to POTW and industrial BOD loadings. Its average reading of close to 9.0 mg/l indicates good oxygenization of the water column. The high level of DO is caused by the relatively high flow over the period and the colder winter temperatures. The season has less sunlight, producing less algae than during the longer summer days. Additionally, oxygen saturation concentrations increase with a decrease in temperatures. The most significant factor controlling the saturation concentration of dissolved oxygen is water temperature

(Lung, 1991).

The parameters and rates used to tune the model were obtained from series of rate and constant tables developed by Dr. Carl Cerco for use on the Chesapeake Bay. The values were interpolated to account for the season and the shift to a smaller localized Estuary system. Table 1 is the variables used for this system.

TABLE 6.1 KINETIC COEFFICIENTS and CONSTANTS IN THE WATER COLUMN

PARAMETER	UNIT	VALUE
RATIO		
DO/C RATIO	gm DO gm^{-1} C	2.67
N/C RATIO	gm N gm^{-1} C	0.167
Si/C RATIO	gm Si gm^{-1} C	0.40
HALF SATURATION		
N	gm M^{-3}	0.01
P	gm M^{-3}	0.001
Si	gm M^{-3}	0.05
RESPIRATION RATE		
DOC	day^{-1}	0.010
POC	day^{-1}	0.075
MINERALIZATION RATE		
DON	day^{-1}	0.015
DOP	day^{-1}	0.100
HYDROLYSIS RATE		
PON	day^{-1}	0.075
POP	day^{-1}	0.075
ALGAE GROWTH RATES		
CYANOBACTERIA	day^{-1}	2.5
DIATOMS	day^{-1}	2.25
GREENS	day^{-1}	2.50

Table 6.1

PARAMETER	UNIT	VALUE
OPTIMAL TEMPERATURES		
NITRIFICATION	C	30.0
CYANOBACTERIA GROWTH	C	27.5
DIATOM GROWTH	C	20.0
ALGAE GROWTH	C	25.0
PREDATION RATE	day $^{-1}$	0.7 - 1.1
ALGAE LIGHT PARAMETERS		
LIGHT ATTENUATION COEFF	m^2 gm $^{-1}$ Chl a	17
MAX DEPTH FOR PRODUCTION	m	1.0
MINIMAL OPTIMAL ILLUM	langley day $^{-1}$	40.0
ALGAE SETTLING RATES		
CYANOBACTERIA	m day $^{-1}$	0.1
DIATOMS	m day $^{-1}$	0.1
GREENS	m day $^{-1}$	0.1
PHOSPHORUS TO CARBON COEFFICIENT	gm C gm $^{-1}$ p	42.0
OXIDATION RATE OF COD	day $^{-1}$	20.0
SILICA DISSOLUTION RATE	day $^{-1}$	0.03
REFERENCE TEMPERATURE		
ALGAE METABOLISM	C	20.0
COD	C	23.0
MINERALIZATION	C	20.0
HYDROLYSIS	C	20.0
SILICA DISSOLUTION	C	20.0
DO TO METAL SOLUBILITY CONC	gm DO m^{-3}	1.0
METAL SOLUBILITY, ANOXIC CONDITIONS	mmol m^{-3}	0.015
BENTHIC RELEASE RATE	mmol m^2 day $^{-1}$	0.73
CARBON TO CHLOROPHYLL RATIO	gm C gm $^{-1}$ Chl	60.0
SURFACE RENEWAL RATE	day $^{-1}$	0.40
BURIAL RATES	cm yr^{-1}	0.23
OPTIMAL GRAZING RATE	day $^{-1}$	1.0
ZOOPLANKTON RESPIRATION RATE	day $^{-1}$	0.05

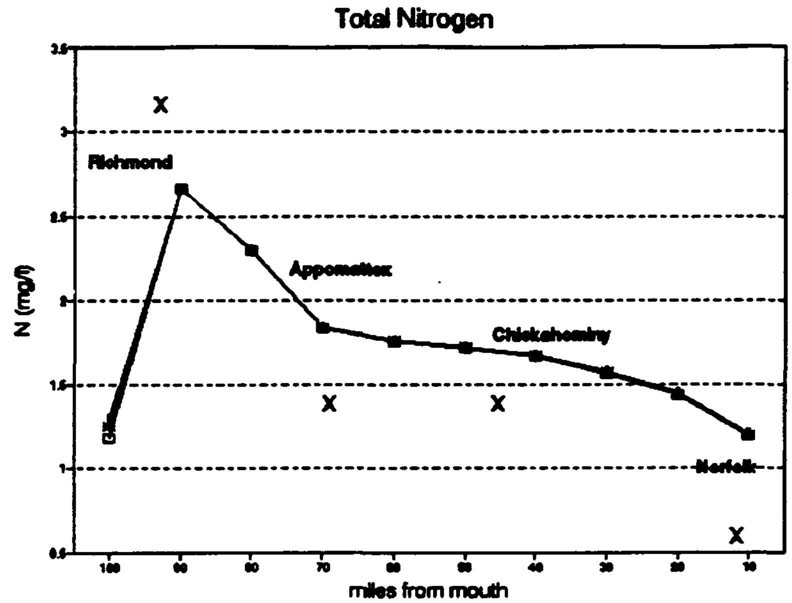
Table 6.1 (cont)

6.5 Sensitivity Analysis

A sensitivity analysis of a model is conducted to ensure model output varies correctly with alterations in input data. For this model, the algae growth rate was varied from its normal rate up and down 50%. When the algae growth rate is increased (see Figure 6.6 - 6.8), a reduction in nutrient levels is witnessed along with a corresponding increase in chlorophyll α and dissolved oxygen. Conversely, when the algae growth rate is reduced, nutrient levels increase and the chlorophyll α and dissolved oxygen levels are reduced. These results support basic loading system models. If the algae growth rate is increased, there is a greater uptake of nutrients from the ecosystem and a corresponding algae bloom increasing chlorophyll α and dissolved oxygen in the system. If the rate is reduced, the opposite effect occurs, as less nutrients are absorbed by the system chlorophyll α and dissolve oxygen attenuate.

6.6 Computational Effort

The Computational effort to run, compile and store input and output from the modeling package is notable. To run and compile the model and its input and output files for a 90 day period requires 10 to 15 megabytes, plus the space occupied by a 32 bit compiler and a spreadsheet or graphics package. Simulations on the 90 day and over scale require super computer assistance to speed up the run time and aide in the constant compiling. For this research, a RS-6000 mainframe computer system, with an internally loaded 32 bit compiler was used. The compilation time for the water quality model was



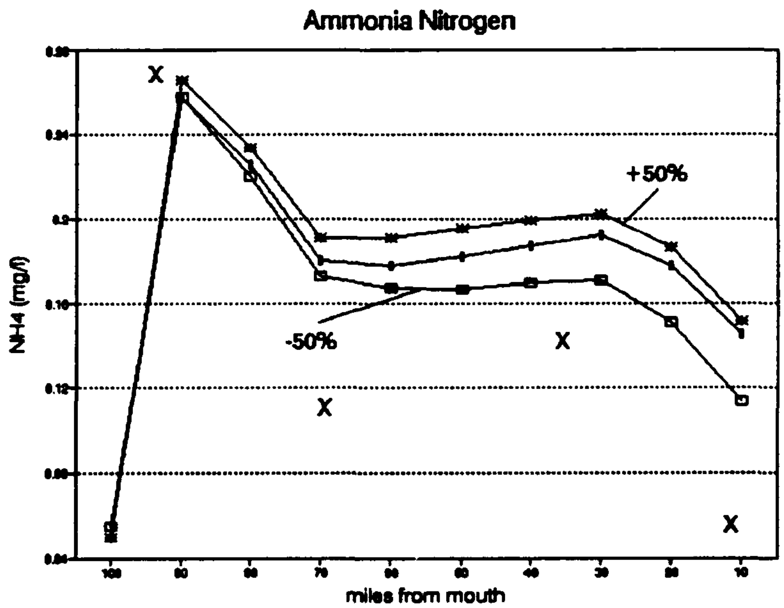
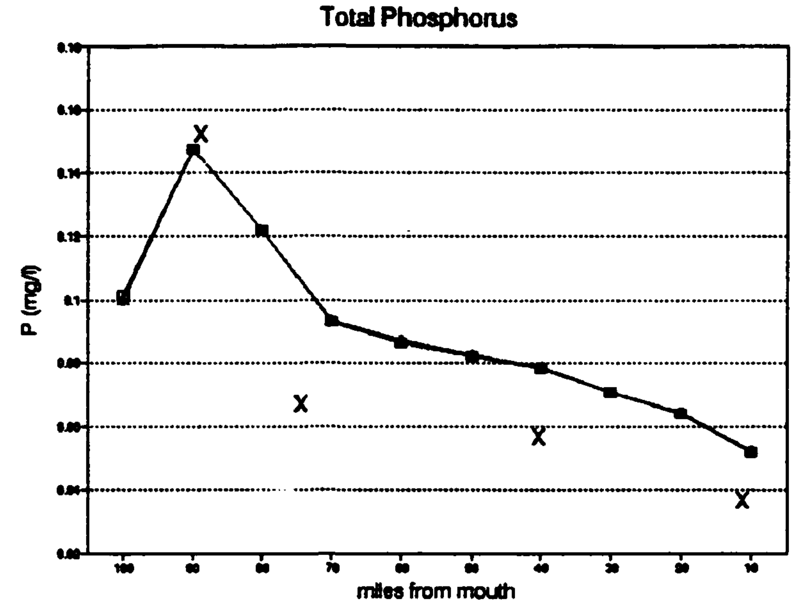


Figure 6.6 Nitrogen Results of the Model



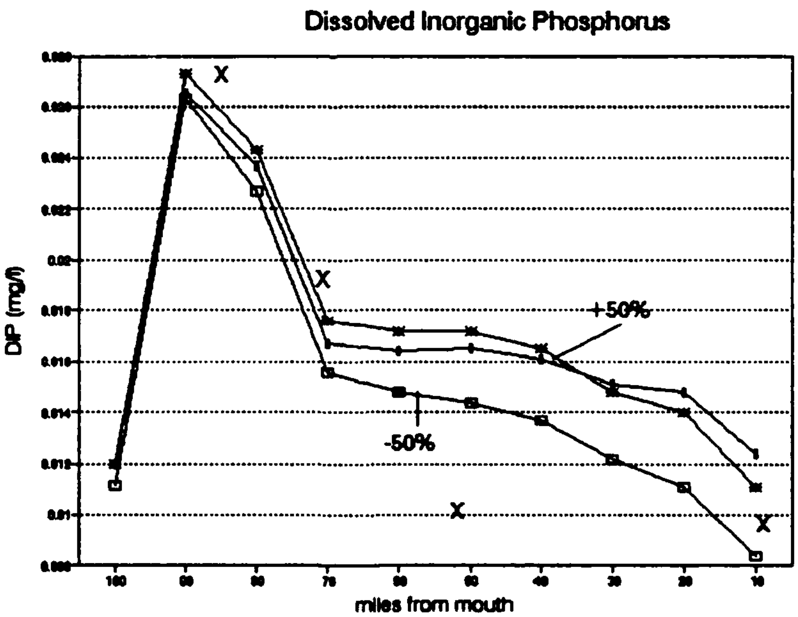
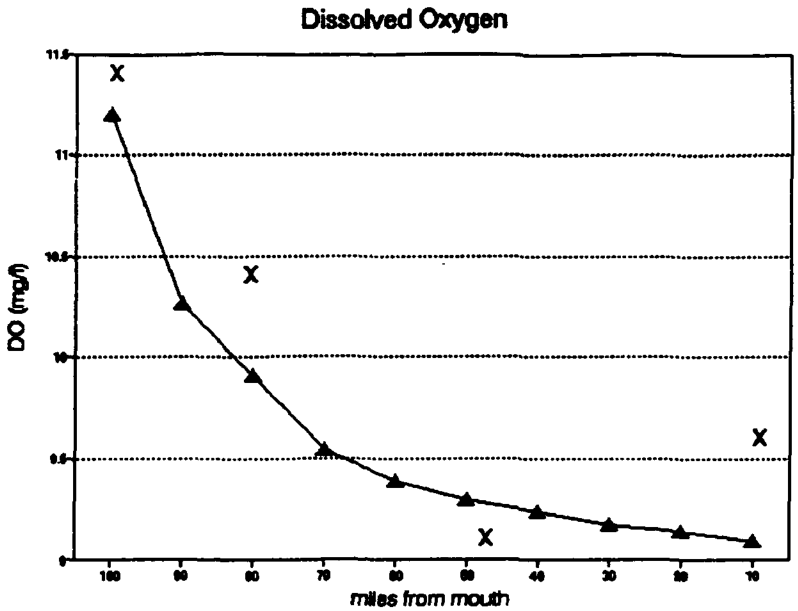


Figure 6.7 Phosphorus Results of the Model



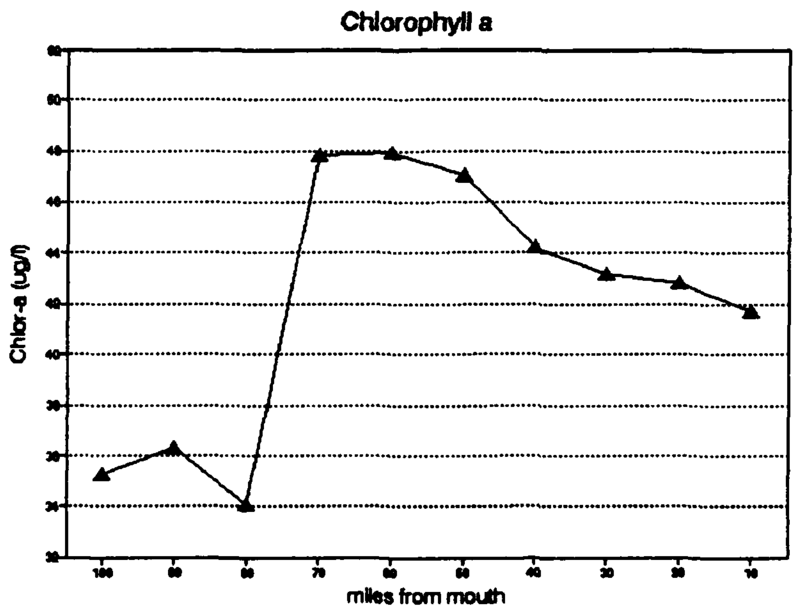


Figure 6.8 Dissolved Oxygen Model Results

3-6 minutes, and run time was 6-10 minutes depending on CPU requirements. Early renditions of the model on an IBM 486 with RMFORT, a 16 bit FORTRAN compiler, required 45-60 minutes to compile, and a runtime of 60-90 minutes, depending on the amount of memory available to the computer. Additionally, the programs are expansive: the hydrodynamic program is close to 15,000 lines and the water quality model is almost 11,000 lines. Making access from the top to the bottom of a program difficult. Movement from one portion of the model to another was very time consuming. The MS-DOS and WATFOR editors would not load either file due to lack of memory, and the PC-Tools editor required about 5 minutes to travel from the top of the program to the bottom. On the R-6000, instantaneous access anywhere in the file was available. The disk space required to save a year of intra tidal hydrodynamic information for the Chesapeake Bay is on the order of a billion bytes (i.e. gigabyte). Similar data for tributaries would require 40 to 50 % or approximately half a gigabyte. These storage and space requirements should be taken into account regarding any consideration for using or receiving output from this modeling framework.

7. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

7.1 Summary

The purpose of this research was to apply the Waterways Experiment Station modeling system to the James River Estuary and obtain reasonable results. The outcome of the simulation proves that the water quality model is well constructed and can be applied to smaller scale estuaries. The major advantages of the model are that it is well organized and the computer code is orderly. With very few hardwires, the modeler is allowed to spend a majority of time manipulating data as opposed to evaluating and altering computer code. Additionally, the input file structure is easy to follow and well established. The independent input files contain similar information making trouble-shooting and data management more efficient. Future research on the water quality model include applying the subaquatic vegetation subroutine to the main program and experimenting with computer programs that can correctly map the boxes and faces required in cell oriented models.

The hydrodynamic model, on the other hand, is a very difficult to operate. The major problem areas are in grid generation mapping and site specific computer code. To run CH3D, a grid generation program WESCORA, first has to be developed. This mapping system is a series of slits and slabs which relay to the computer positions and locations. This program contains almost as many input files as the hydrodynamic program. Additionally, the computer code includes a series of hardwires to accomplish the hydrodynamics of the Chesapeake Bay. Application of

the model to other ecosystems proves difficult. Portions of the computer code must be constantly altered or updated. The code contains approximately two hundred lines of computer modeling specific only to the Chesapeake Bay. With little or no documentation on the locations and reasons for these loops, the modeler is forced to troubleshoot the system without guidance. Although the hydrodynamic model successfully ran for the James River Estuary, the results were unreliable, and a steady state, balanced flow was used to operate the water quality model. Further research on this model would concentrate on reducing the coding discrepancies and developing a grid generation mapping program.

7.2 Conclusions

The Chesapeake Bay modeling framework is a complicated tool that relates nutrient loadings to dissolved oxygen responses. The information it provides its users is invaluable in making decisions and producing strategies to improve aquatic quality in an ecosystem. Presently, the water quality model is transparent, and could be applied to any of the Bay tributaries; subsequently reasonably accurate results can be attained. The hydrodynamic model, however, is oriented on the Chesapeake Bay, and its use on major tributaries will require a significant amount of reprogramming to agree with the selected basin.

7.3 Recommendations

Future modeling of the Chesapeake Bay will orient on subaquatic life forms, and the influence pollution is having on their existence. Additionally, tributaries to the Bay will be required to develop a clean up strategy to improve their water

quality, and in turn the Chesapeake Bays, water quality. To accomplish these goals, the WES modeling package will need to transform the hydrodynamic model so that it is applicable to all tributaries. In its present condition, site specific coding forces modelers to obtain hydrodynamic information from outside sources. As the models focus on sub aquatic vegetation, their resolution will have to be reduced. This will require a mapping model for the water quality and hydrodynamic model. A program to map the basin we greatly alleviate present problems in locating all the boxes and faces in the model.

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APPENDIX A

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************************************************************************
**                                                                    **
**                    COMMON file for CE-QUAL-IC                      **
**                                                                    **
**                           Version 1.1                              **
**                          July 28, 1992                             **
**                                                                    **
**                   Water Quality Modeling Group                     **
**                   U.S. Army Corps of Engineers                     **
**                   Waterways Experiment Station                     **
**                   Vicksburg, Mississippi 39180                     **
**                                                                    **
************************************************************************

************************************************************************
**                                                                    **
**                      PARAMETER definitions                         **
**                                                                    **
**    NBP   - Number of boxes                                         **
**    NQFP  - Number of horizontal and vertical flow faces            **
**    NHQP  - Number of horizontal flow faces                         **
**    NSBP  - Number of boxes in the surface layer                    **
**    NLP   - Maximum number of layers                                **
**    NPSP  - Number of point source inputs                           **
**    NNPSP - Number of non-point source inputs                       **
**    NBCP  - Number of boundary concentration inputs                 **
**    NMP   - Number of modifications to initial box concentrations   **
**    NDP   - Maximum number of days for any output                   **
**    NFLP  - Number of files for each type of time-varying data      **
**    NFBP  - Number of kinetic flux boxes to be output               **
**    NCP   - Number of constituent state variables                   **
**                                                                    **
************************************************************************


************************************************************************
**                     Water Quality Model Setup                      **
************************************************************************


***** Parameter declarations

      PARAMETER (NCP=22)
C     PARAMETER (NBP=4073,NQFP=9874,NHQP=6530,NSBP=729,NLP=15,NPSP=600,    !CHESAPEA]
C    .           NNPSP=50,NBCP=120,NMP=30,NDP=500,NSAVP=729,NFLP=100,      !CHESAPEA]
C    .           NFBP=100,NOIP=10)                                         !CHESAPEA]
      PARAMETER (NBP=68,NQFP=149,NHQP=97,NSBP=16,NLP=6,NPSP=20,            !CLASS
     .           NNPSP=20,NBCP=30,NMP=20,NDP=500,NSAVP=50,NFLP=10,         !CLASS
     .           NFBP=50,NOIP=10)                                          !CLASS

***** Data type declarations

      INTEGER B,      SBN,    BB,     BU,     BBN,    VFN,    PSLB,
     .        PSLN,   SAVB,   AC
      INTEGER DIA,    HYD,    CBC,    PS,     NPS,    BFI,    BFO,
     .        ATM,    STL,    AGR,    SAV
      INTEGER HYDPTR, METPTR, CBCPTR, PSPTR,  NPSPTR, BFIPTR, KEIPTR,
     .        ATMPTR, SAVPTR, PRDDP
      REAL    KHRC,   KHRD,   KHRG,   KHNC,   KHND,   KHNG,   KHPC,
     .        KHPD,   KHPG,   KHSD,   KHONT,  KHOCOD, KHNNT,  KHODOC,
     .        KHTIS,  NPSL,   KHNDN
      REAL    KDC,    KDCALG, KLC,    KLCALG, KRC,    KRCALG, KCOD
      REAL    KHSO,   KHSNH4, KHSNO3, KHSPO4
      REAL    KDN,    KDNALG, KDP,    KDPALG, KLN,    KLNALG, KLP,
     .        KLPALG, KRN,    KRNALG, KRP,    KRPALG, KHNAVG, KHPAVG
      REAL    KSO,    KSNH4,  KSNO3,  KSPO4
```

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      REAL    KTNT1,  KTGC1,  KTGD1,  KTGG1,  KTNT2,  KTGC2,  KTGD2,
     .        KTGG2,  KTBC,   KTBD,   KTBG,   KTCOD,  KTMNL,  KTHDR,
     .        KTSUA
      REAL    LPOC,   LPON,   LPOP,   MNLDOC, MTVEL
      REAL    NT,     KT,     NXCBC,  NXPRD,  JDAY,   JDAYMBL
      REAL    KE,     KECHL,  KESS
      REAL    I0,     I1,     I2,     I0NX,   ISMIN,  I0AVG,  I0WT,
     .        I1WT,   I2WT
      REAL    NTM,    MBGM,   KSUA,   NPP,    NH4,    NO3,    NLC,
     .        NLD,    NLG
      REAL    KDOTAM, KADPO4, KADSA,  KTBMF,  KHBMF
      LOGICAL BOUNDARY_CONC,  POINT_SOURCES,     NONPOINT_SOURCES,
     .        BENTHIC_FLUXES, SEDIMENT_CALC,     LIGHT_EXTINCTION,
     .        ATMOS_LOADS,    TRANSPORT_FLUXES,  SUB_AQ_VEG_CALC,
     .        AVERAGE_PLOTS,  SALINITY_RUN,      QUALITY_DIAG,
     .        SEDIMENT_DIAG,  DIAGNOSTICS,       CONSERVE_MASS,
     .        SETTLING,       STEP_BOUNDARY,     MASS_BALANCE
      LOGICAL POSITIVE_FLOW,  FLOW,              XY_DIFFUSION,
     .        Z_DIFFUSION,    CH3D_HYDRO,        HYDROQUAL_HYDRO,
     .        DEPTH_AVG_HYDRO
      CHARACTER*20 SSNAME
      CHARACTER*72 BFOFN
      CHARACTER*72 METFN,  PSFN,   NPSFN,  HYDFN,  CBCFN,  KEIFN,
     .             ATMFN,  SAVFN,  BFIFN

***** Dimension declarations

      DIMENSION POSITIVE_FLOW(NQFP)
      DIMENSION NVF(NSBP),         VFN(0:NLP,NSBP)
      DIMENSION BFLUX(NSBP,9),     BFLUXB(NSBP,6)
      DIMENSION C1(0:NBP,NCP),     C2(0:NBP,NCP),     CSTAR(0:NBP,NCP),
     .          DTC(0:NBP,NCP),    AC1(0:NBP,NCP),    CMASS(NCP)
      DIMENSION PSL(NPSP,NCP),     NPSL(NNPSP,NCP),   PSLB(NPSP,NCP),
     .          NPSLB(NNPSP,NCP),  CB(NBCP,NCP),      CBNX(NBCP,NCP),
     .          SAVB(NSAVP),       SAVAREA(NSAVP)
      DIMENSION CPOP(NSBP,3),      FLXPOP(NSBP,3),    CPON(NSBP,3),
     .          FLXPON(NSBP,3),    CPOC(NSBP,3),      FLXPOC(NSBP,3),
     .          CPOS(NSBP),        CPIP(NSBP),        CNO3(NSBP),
     .          CNH4(NSBP),        FLXPOS(NSBP),      CTEMP(NSBP),
     .          CDTEMP(NSBP),      BSVOL(NSBP),       HSED(NSBP)
      DIMENSION ATMFLXNB(NSBP),    ATMFLXPB(NSBP),    ATMFLXCB(NSBP),
     .          BENFLXPNB(NSBP),   BENFLXDNB(NSBP),   BENFLXPPB(NSBP),
     .          BENFLXDPB(NSBP),   BENFLXPCB(NSBP),   DLSEDKNB(NSBP),
     .          DLSEDKCB(NSBP),
     .          BURIALFLXNB(NSBP),BURIALFLXPB(NSBP),BURIALFLXCB(NSBP)
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      DIMENSION FLXTTEM(NQFP),     FLXTSAL(NQFP),     FLXTSSI(NQFP),
     .          FLXTC(NQFP),       FLXTD(NQFP),       FLXTG(NQFP),
     .          FLXTDOC(NQFP),     FLXTLPOC(NQFP),    FLXTRPOC(NQFP),
     .          FLXTNH4(NQFP),     FLXTNO3(NQFP),     FLXTDON(NQFP),
     .          FLXTLPON(NQFP),    FLXTRPON(NQFP),    FLXTPO4(NQFP),
     .          FLXTDOP(NQFP),     FLXTLPOP(NQFP),    FLXTRPOP(NQFP),
     .          FLXTCOD(NQFP),     FLXTDO(NQFP),      FLXTSU(NQFP),
     .          FLXTSA(NQFP)
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     .          FLXSG(NBP),        FLXSPOC(NBP),      FLXSPON(NBP),
     .          FLXSPO4(NBP),      FLXSPOP(NBP),      FLXSSI(NBP)
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     .          ACPOC(NSBP,3),     ACPON(NSBP,3),     ACPOP(NSBP,3),
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     .         ACPIP(NSBP),      ACPOS(NSBP)
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      DIMENSION PSLN(NCP),     NPSLN(NCP),     NCB(NCP),       AC(NCP),
     .         ALPHAB(NCP)
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     .         JRB(0:NQFP),    A(0:NQFP),      DIFF(0:NQFP)
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     .         HMV(0:NBP),     HMBV(NSBP),     ZD(0:NBP),      BU(0:NBP)
      DIMENSION PNC(NBP),      PND(NBP),       PNG(NBP),       BMC(NBP),
     .         BMD(NBP),       BMG(NBP),       MNLDOC(NBP),    FTCOD(NBP),
     .         NPP(NBP),       PC(NBP),        PD(NBP),        PG(NBP),
     .         NT(NBP),        PRC(NBP),       PRD(NBP),       PRG(NBP),
     .         DENIT(NBP),     RATOX(NBP)
      DIMENSION AFIC(NBP),     ANLC(NBP),      APLC(NBP),      AFID(NBP),
     .         ANLD(NBP),      APLD(NBP),      ASLD(NBP),      AFIG(NBP),
     .         ANLG(NBP),      APLG(NBP),      ANPP(NBP),      ARESP(NBP),
     .         AKE(NBP)
      DIMENSION T(0:NBP),      SSI(0:NBP),     BC(0:NBP),      BD(0:NBP),
     .         BG(0:NBP),      DOC(0:NBP),     LPOC(0:NBP),    RPOC(0:NBP),
     .         NH4(0:NBP),     NO3(0:NBP),     DON(0:NBP),     LPON(0:NBP),
     .         RPON(0:NBP),    PO4(0:NBP),     DOP(0:NBP),     LPOP(0:NBP),
     .         RPOP(0:NBP),    COD(0:NBP),     DO(0:NBP),      SU(0:NBP),
     .         SA(0:NBP),      SALT(0:NBP),    TAMP(0:NBP)
      DIMENSION WSS(0:NBP),    WSL(0:NBP),     WSR(0:NBP),     WSC(0:NBP),
     .         WSD(0:NBP),     WSDB(0:NBP),    WSDS(0:NBP),    WSG(0:NBP),
     .         APC(0:NBP)
      DIMENSION PMC(NBP),      PMD(NBP),       PMG(NBP),       BMRC(NBP),
     .         BMRD(NBP),      BMRG(NBP),      BPRC(NBP),      BPRD(NBP),
     .         BPRG(NBP)
      DIMENSION DTT(NBP),      DTSSI(NBP),     DTBC(NBP),      DTBD(NBP),
     .         DTBG(NBP),      DTDOC(NBP),     DTLPOC(NBP),    DTRPOC(NBP),
     .         DTNH4(NBP),     DTNO3(NBP),     DTDON(NBP),     DTLPON(NBP),
     .         DTRPON(NBP),    DTPO4(NBP),     DTDOP(NBP),     DTLPOP(NBP),
     .         DTRPOP(NBP),    DTCOD(NBP),     DTDO(NBP),      DTSU(NBP),
     .         DTSA(NBP)
      DIMENSION KE(NBP),       FIC(NBP),       FID(NBP),       FIG(NBP),
     .         NLC(NBP),       NLD(NBP),       NLG(NBP),       PLC(NBP),
     .         PLD(NBP),       PLG(NBP),       SLD(NBP),       RESP(NBP),
     .         KESS(NBP)
      DIMENSION FTMNL(NBP),    FTHDR(NBP)
      DIMENSION RESPC(NBP),    DLALGC(NBP)
      DIMENSION IWCMNB(NBP),   IWCMPB(NBP),    IWCMCB(NBP),    IWCMSB(NBP),
     .         WCMNB(NBP),     WCMPB(NBP),     WCMCB(NBP),     WCMSB(NBP),
     .         DLWCMNB(NBP),   DLWCMPB(NBP),   DLWCMCB(NCP),   DLWCKMNB(NBP),
     .         DLWCKMCB(NBP),PSFLXNB(NBP),   PSFLXPB(NBP),   PSFLXCB(NBP),
     .         NPSFLXNB(NBP),NPSFLXPB(NBP),NPSFLXCB(NBP)
      DIMENSION BENDOC(NSBP),  BENNH4(NSBP),   BENNO3(NSBP),   BENDON(NSBP),
     .         BENDOP(NSBP),   BENPO4(NSBP),   BENCOD(NSBP),   BENDO(NSBP),
     .         BENSA(NSBP),    BENDEN(NSBP)
      DIMENSION BENDOCB(NSBP),BENNH4B(NSBP),BENNO3B(NSBP),BENPO4B(NSBP),
     .         BENCODB(NSBP),BENDOB(NSBP)
      DIMENSION SBN(NSBP),     BBN(NSBP),      HMSBV(NSBP),    SFA(NSBP)
      DIMENSION WSSNET(NSBP),  WSLNET(NSBP),   WSRNET(NSBP),   WSCNET(NSBP),
     .         WSDNET(NSBP),   WSGNET(NSBP),   VSED(NSBP),     VPMIX(NSBP),
     .         VDMIX(NSBP),    JDIAGP(NSBP),   JDIAGN(NSBP),   JDIAGC(NSBP),
     .         JDIAGS(NSBP),   IWCSEG(NSBP),   MTVEL(NSBP)
      DIMENSION PPFWS(NSBP),   PNFWS(NSBP),    PCFWS(NSBP),    PSFWS(NSBP),
     .         SSFWS(NSBP)
      DIMENSION METFN(NFLP),   PSFN(NFLP),     NPSFN(NFLP),    HYDFN(NFLP),
     .         CBCFN(NFLP),    KEIFN(NFLP),    ATMFN(NFLP),    SAVFN(NFLP),
     .         BFIFN(NFLP)
      DIMENSION KFLB(NFBP),    KFLBB(NFBP)
      DIMENSION FRPPH1(3),     FRPPH2(3),      FRPPH3(3),   FRPOP(NSBP,3),
     .         FRNPH1(3),      FRNPH2(3),      FRNPH3(3),   FRPON(NSBP,3),
     .         FRCPH1(3),      FRCPH2(3),      FRCPH3(3),   FRPOC(NSBP,3)
      DIMENSION PRDD(500),     PRDVAL(500)
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      DIMENSION SSNAME(11)
      DIMENSION HQCFA(NHQP/NLP)

***** Equivalence declarations

      EQUIVALENCE (NSB,         NBB)
      EQUIVALENCE (C1(0,1),     CSTAR(0,1))
      EQUIVALENCE (T(0),        C2(0,1)),     (SALT(0),     C2(0,2)),
     .            (SSI(0),      C2(0,3)),     (BC(0),       C2(0,4)),
     .            (BD(0),       C2(0,5)),     (BG(0),       C2(0,6)),
     .            (DOC(0),      C2(0,7)),     (LPOC(0),     C2(0,8)),
     .            (RPOC(0),     C2(0,9)),     (NH4(0),      C2(0,10)),
     .            (NO3(0),      C2(0,11)),    (DON(0),      C2(0,12)),
     .            (LPON(0),     C2(0,13)),    (RPON(0),     C2(0,14)),
     .            (PO4(0),      C2(0,15)),    (DOP(0),      C2(0,16)),
     .            (LPOP(0),     C2(0,17)),    (RPOP(0),     C2(0,18)),
     .            (COD(0),      C2(0,19)),    (DO(0),       C2(0,20)),
     .            (SU(0),       C2(0,21)),    (SA(0),       C2(0,22))
      EQUIVALENCE (DTT(1),      DTC(1,1)),    (DTSSI(1),    DTC(1,3)),
     .            (DTBC(1),     DTC(1,4)),    (DTBD(1),     DTC(1,5)),
     .            (DTBG(1),     DTC(1,6)),    (DTDOC(1),    DTC(1,7)),
     .            (DTLPOC(1),   DTC(1,8)),    (DTRPOC(1),   DTC(1,9)),
     .            (DTNH4(1),    DTC(1,10)),   (DTNO3(1),    DTC(1,11)),
     .            (DTDON(1),    DTC(1,12)),   (DTLPON(1),   DTC(1,13)),
     .            (DTRPON(1),   DTC(1,14)),   (DTPO4(1),    DTC(1,15)),
     .            (DTDOP(1),    DTC(1,16)),   (DTLPOP(1),   DTC(1,17)),
     .            (DTRPOP(1),   DTC(1,18)),   (DTCOD(1),    DTC(1,19)),
     .            (DTDO(1),     DTC(1,20)),   (DTSU(1),     DTC(1,21)),
     .            (DTSA(1),     DTC(1,22))
      EQUIVALENCE (FLXTTEM(1), FLUXT(1,1)),   (FLXTSAL(1),  FLUXT(1,2)),
     .            (FLXTSSI(1), FLUXT(1,3)),   (FLXTC(1),    FLUXT(1,4)),
     .            (FLXTD(1),   FLUXT(1,5)),   (FLXTG(1),    FLUXT(1,6)),
     .            (FLXTDOC(1), FLUXT(1,7)),   (FLXTLPOC(1), FLUXT(1,8)),
     .            (FLXTRPOC(1),FLUXT(1,9)),   (FLXTNH4(1),  FLUXT(1,10)),
     .            (FLXTNO3(1), FLUXT(1,11)),  (FLXTDON(1),  FLUXT(1,12)),
     .            (FLXTLPON(1),FLUXT(1,13)),  (FLXTRPON(1), FLUXT(1,14)),
     .            (FLXTPO4(1), FLUXT(1,15)),  (FLXTDOP(1),  FLUXT(1,16)),
     .            (FLXTLPOP(1),FLUXT(1,17)),  (FLXTRPOP(1), FLUXT(1,18)),
     .            (FLXTCOD(1), FLUXT(1,19)),  (FLXTDO(1),   FLUXT(1,20)),
     .            (FLXTSU(1),  FLUXT(1,21)),  (FLXTSA(1),   FLUXT(1,22))
      EQUIVALENCE (FLXSSSI(1), FLUXS(1,1)),   (FLXSC(1),    FLUXS(1,2)),
     .            (FLXSD(1),   FLUXS(1,3)),   (FLXSG(1),    FLUXS(1,4)),
     .            (FLXSPOC(1), FLUXS(1,5)),   (FLXSPON(1),  FLUXS(1,6)),
     .            (FLXSPO4(1), FLUXS(1,7)),   (FLXSPOP(1),  FLUXS(1,8)),
     .            (FLXSSI(1),  FLUXS(1,9))
      EQUIVALENCE (AFLXPOC(1), AFLUX(1,1)),   (AFLXDOC(1),  AFLUX(1,2)),
     .            (AFLXTC(1),  AFLUX(1,3)),   (AFLXDON(1),  AFLUX(1,4)),
     .            (AFLXDIN(1), AFLUX(1,5)),   (AFLXPON(1),  AFLUX(1,6)),
     .            (AFLXTN(1),  AFLUX(1,7)),   (AFLXDOP(1),  AFLUX(1,8)),
     .            (AFLXDIP(1), AFLUX(1,9)),   (AFLXPOP(1),  AFLUX(1,10)),
     .            (AFLXTP(1),  AFLUX(1,11))
      EQUIVALENCE (BENDOC(1),  BFLUX(1,1)),   (BENNH4(1),   BFLUX(1,2)),
     .            (BENNO3(1),  BFLUX(1,3)),   (BENDON(1),   BFLUX(1,4)),
     .            (BENPO4(1),  BFLUX(1,5)),   (BENDOP(1),   BFLUX(1,6)),
     .            (BENCOD(1),  BFLUX(1,7)),   (BENDO(1),    BFLUX(1,8)),
     .            (BENSA(1),   BFLUX(1,9))
      EQUIVALENCE (BENDOCB(1), BFLUXB(1,1)),  (BENNH4B(1),  BFLUXB(1,2)),
     .            (BENNO3B(1), BFLUXB(1,3)),  (BENPO4B(1),  BFLUXB(1,4)),
     .            (BENCODB(1), BFLUXB(1,5)),  (BENDOB(1),   BFLUXB(1,6))

***** Common declarations

      COMMON /TVDLGC/ BOUNDARY_CONC,   POINT_SOURCES,   NONPOINT_SOURCES,
     .                BENTHIC_FLUXES,  SEDIMENT_CALC,   LIGHT_EXTINCTION,
     .                ATMOS_LOADS,     SUB_AQ_VEG_CALC,STEP_BOUNDARY
      COMMON /HYDLGC/ POSITIVE_FLOW,   FLOW,            XY_DIFFUSION,
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     .                  Z_DIFFUSION,  DIAGNOSTICS,  CH3D_HYDRO,
     .                  CONSERVE_MASS, MASS_BALANCE, HYDROQUAL_HYDRO,
     .                  DEPTH_AVG_HYDRO
      COMMON /AVGLGC/ AVERAGE_PLOTS, SALINITY_RUN,  QUALITY_DIAG,
     .                  SEDIMENT_DIAG
      COMMON /SEDLGC/ SETTLING
      COMMON /HYDROC/ Q,      A,      DIFF,   HMBV,   HMSBV,  HMV,
     .                  HQCFA,  SFA,    ILB,    IB,     JB,     JRB,
     .                  VFN,    NVF,    DLT,    AHMDLT, NHMDLT, NWQMR,
     .                  NHMR,   ZDFMUL, ELTMS,  HMEND,  JDAY,   NIT
      COMMON /TVDSC/  PSL,    PSLB,   PSLN,   NPSL,   NPSLB,  NPSLN,
     .                  CB,     NCB,    NXCBC,  CBNX,   ALPHAB, TMEND
      COMMON /AVGC1/  AC,     NAC,    AC1,    ATAMP,  AAPC
      COMMON /AVGC2/  ABENDOC,ABENNH4,ABENNO3,ABENPO4,ABENCOD,ABENDO,
     .                  ABENSA, ASSFWS, APCFWS, APNFWS, APPFWS, APSFWS,
     .                  ACPOC,  ACPON,  ACPOP,  ACPIP,  ACPOS
      COMMON /AVGC3/  AFIC,   ANLC,   APLC,   AFID,   ANLD,   APLD,
     .                  ASLD,   AFIG,   ANLG,   APLG,   ANPP,   ARESP,
     .                  AKE
      COMMON /UNITNC/ HYD,    DIA,    CBC,    PS,     NPS,    BFI,
     .                  MET,    BFO,    KEI,    ATM,    STL,    AGR,
     .                  SAV,    KFL
      COMMON /GEOMC/  BL,     V1,     V2,     BU,     SBN,    BBN,
     .                  ZD,     NB,     NQF,    NL,     NSB,    NHQF,
     .                  NSQF
      COMMON /TEMPC/  KT,     TE
      COMMON /SOLIDC/ KDOTAM, KADPO4, KADSA,  BENTAM, KTBMF,  KHBMF,
     .                  TAMP,   TAMDMX
      COMMON /OXYGNC/ AOCR,   AONT,   DL,     R,      FTCOD,  FDOP
      COMMON /CODMDC/ KCOD,   TRCOD,  KTCOD
      COMMON /SILICC/ ASCD,   KSUA,   FSAP,   KTSUA,  TRSUA
      COMMON /NITROC/ TMNT,   NTM,    KTNT1,  KTNT2,  KHONT,  KHNNT,
     .                  ANCC,   ANCD,   ANCG,   FNIC,   KDN,    KDNALG,
     .                  KLN,    KLNALG, KRN,    KRNALG, KHNAVG, FNID,
     .                  FNIG,   FNDC,   FNDD,   FNDG,   FNLC,   FNLD,
     .                  FNLG,   FNRC,   FNRD,   FNRG,   FNIP,   FNDP,
     .                  FNLP,   FNRP,   NT,     KHNDN,  DENIT,  ANDC
      COMMON /PHOSPC/ APC,    PCPRM1, PCPRM2, PCPRM3, FPIC,   FPID,
     .                  FPIG,   FPDC,   FPDD,   FPDG,   FPLC,   FPLD,
     .                  FPLG,   FPRC,   FPRD,   FPRG,   FPIP,   FPDP,
     .                  FPLP,   FPRP,   KDP,    KDPALG, KLP,    KLPALG,
     .                  KRP,    KRPALG, KHPAVG
      COMMON /CARBC/  FCDC,   FCDD,   FCDG,   FCDP,   FCLP,   FCRP,
     .                  KTMNL,  KTHDR,  TRMNL,  TRHDR,  FTMNL,  FTHDR,
     .                  KDC,    KDCALG, KLC,    KLCALG, KRC,    KRCALG,
     .                  MNLDOC, RATOX,  AANOX
      COMMON /ALGAEC/ TMC,    TMD,    TMG,    KTGC1,  KTGC2,  KTGD1,
     .                  KTGD2,  KTGG1,  KTGG2,  KHPC,   KHPD,   KHPG,
     .                  KHSD,   BMRC,   BMRD,   BMRG,   TRC,    TRD,
     .                  TRG,    KTBC,   KTBD,   KTBG,   PMC,    PMD,
     .                  PMG,    MBGM,   UCM,    UDM,    UGM,    FR,
     .                  PRC,    PRD,    PRG,    BPRC,   BPRD,   BPRG,
     .                  SCTOX
      COMMON /SED1C/  CPOP,   FLXPOP, CPON,   FLXPON, CPOC,   FLXPOC,
     .                  CPOS,   CPIP,   CNO3,   CNH4,   FLXPOS, CTEMP,
     .                  CDTEMP, BSVOL,  WSSNET, WSCNET, WSDNET, WSGNET,
     .                  WSLNET, WSRNET, IWCSEG, HSED,   VSED,   VPMIX,
     .                  VDMIX,  JDIAGP, JDIAGN, JDIAGC, JDIAGS, RESTART_IN
      COMMON /SED2C/  FRPPH1, FRPPH2, FRPPH3, FRPOP,  FRNPH1, FRNPH2,
     .                  FRNPH3, FRPON,  FRCPH1, FRCPH2, FRCPH3, FRPOC
      COMMON /SED4C/  SSNAME
      COMMON /CONSTC/ C1,     C2,     DTC
      COMMON /FLUXC/  FLUXT,  FLUXS,  AFLUX,  TRANSPORT_FLUXES
      COMMON /PRODC/  PC,     PD,     PG
      COMMON /RESPRC/ BMC,    BMD,    BMG
      COMMON /NPREFC/ PNC,    PND,    PNG
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      COMMON /SETTLC/ WSS,     WSC,     WSD,     WSG,     WSL,     WSR,
     .                WSDB,    WSDS
      COMMON /HALFSC/ KHNC,    KHND,    KHNG,    KHRC,    KHRD,    KHRG,
     .                KHOCOD,  KHODOC
      COMMON /LIGHTC/ FD,      KE,      I0,      I1,      I2,      I0NX,
     .                KHTIS,   CCHLC,   CCHLD,   CCHLG,   KECHL,   I0WT,
     .                I1WT,    I2WT,    ISMIN,   DOPTC,   DOPTD,   DOPTG,
     .                I0AVG,   FCYAN,   KESS
      COMMON /ATMC/   PRECIP,  ATMNH4,  ATMNO3,  ATMDON,  ATMPO4,  ATMDOP
      COMMON /SAVC/   NSAV,    SAVB,    SAVAREA,SAVLPOC,SAVRPOC,SAVLPON,
     .                SAVRPON,SAVLPOP,SAVRPOP,SAVDO
      COMMON /BENTHC/ KSO,     KSNH4,   KSNO3,   KSPO4,   TRSO,    TRSNH4,
     .                TRSNO3,  TRSPO4,  KHSO,    KHSNH4,  KHSNO3,  KHSPO4,
     .                BFLUX,   BFLUXB,  BENDEN,  MTVEL
      COMMON /DIAPLC/ FIC,     FID,     FIG,     NLC,     NLD,     NLG,
     .                PLC,     PLD,     PLG,     SLD,     RESP,    NPP
      COMMON /BENPLC/ PPFWS,   PNFWS,   PCFWS,   PSFWS,   SSFWS
      COMMON /FILENC/ METFN,   PSFN,    NPSFN,   HYDFN,   CBCFN,   KEIFN,
     .                ATMFN,   SAVFN,   BFIFN,   BFOFN
      COMMON /POINTC/ HYDPTR,  METPTR,  CBCPTR,  PSPTR,   NPSPTR,  BFIPTR,
     .                KEIPTR,  ATMPTR,  SAVPTR
      COMMON /KFLXC/  NKFLB,   NKFLBB,  KFLB,    KFLBB
      COMMON /REDUCC/ REDPSC,  REDPSN,  REDPSP,  REDNPC,  REDNPN,  REDNPP,
     .                REDCBC,  REDCBN,  REDCBP
      COMMON /PREDC/  NXPRD,   PRDDP,   PRDD,    PRDVAL
      COMMON /MASSBC/ DLALGC,  RESPC


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**                         Sediment Model Setup                       **
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***** Variable declarations

      REAL     M1,         M2,          KAPPNH4F, KMNH4,     KMNH4O2,
     .         KAPPNO3F,  K2NO3,       KAPPD1,   KAPPP1,    KMHSO2,
     .         KSI,       KMPSI,       KMO2DP,   KBENSTR,
     .         KAPPCH4,   KPDIAG,      KNDIAG,   KCDIAG,    KAPPNH4S,
     .         KAPPNO3S,  O2CRITSI,    JSIDETR,  KLBNTH,    DPMIN
      REAL     K0H1D,     K0H1P,       K1H1D,    K1H1P,     K2H2D,
     .         K2H2P,     K3,          J1,       J2,        KMC1,
     .         KL12,      KL12NOM,     ISWBENS
      REAL     NH41TM1S,  NH4T2TM1S,   NO31TM1S, NO3T2TM1S
      REAL     NH40,      NH41,        NH42,     NH4T1,      NH4T2,
     .         NH41TM1,   NH4T2TM1,    JNH4,     NO30,       NO31,
     .         NO32,      NO3T1,       NO3T2,    NO31TM1,    NO3T2TM1,
     .         JNO3,      JHS,         JSI,      JPO4,       JCH4AQ,
     .         JCH4G,     JO2NH4
      REAL     KPOP1,     KPOP2,       KPOP3,    KPON1,      KPON2,
     .         KPON3,     KPOC1,       KPOC2,    KPOC3
      REAL     ISEDMN,    ISEDMP,      ISEDMC,   NPSFLXN,    NPSFLXP,
     .         NPSFLXC,   NPSFLXNB,    NPSFLXPB, NPSFLXCB,   IWCMN,
     .         IWCMP,     IWCMC
      LOGICAL BENTHIC_OUTPUT, STEADY_STATE_SED

***** Dimension declarations

      DIMENSION KPDIAG(3),         DPTHTA(3),         KNDIAG(3),
     .          DNTHTA(3),         KCDIAG(3),         DCTHTA(3)
      DIMENSION PON1TM1S(NSBP),    PON2TM1S(NSBP),    PON3TM1S(NSBP),
     .          POC1TM1S(NSBP),    POC2TM1S(NSBP),    POC3TM1S(NSBP),
     .          POP1TM1S(NSBP),    POP2TM1S(NSBP),    POP3TM1S(NSBP),
     .          PSITM1S(NSBP),     BENSTR1S(NSBP),    BFORMAXS(NSBP),
     .          ISWBENS(NSBP)
      DIMENSION NH41TM1S(NSBP),    NH4T2TM1S(NSBP),   NO31TM1S(NSBP),
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     .              NO3T2TM1S(NSBP), HS1TM1S(NSBP),    HST2TM1S(NSBP),
     .              SI1TM1S(NSBP),   SIT2TM1S(NSBP),   PO41TM1S(NSBP),
     .              PO4T2TM1S(NSBP)
      DIMENSION BURIALN(NSBP),    BURIALP(NSBP),    BURIALC(NSBP),
     .              DIAGENC(NSBP)
      DIMENSION ZHTADP(350),      ZHTADD(350),      ZHTANH4F(350),
     .              ZHTANO3F(350),    ZHTA2NO3(350),    ZHTAD1(350),
     .              ZHTAP1(350),      ZHTASI(350),      ZL12NOM(350),
     .              ZW12NOM(350),     ZHTAPON1(350),    ZHTAPON2(350),
     .              ZHTAPON3(350),    ZHTAPOC1(350),    ZHTAPOC2(350),
     .              ZHTAPOC3(350),    ZHTAPOP1(350),    ZHTAPOP2(350),
     .              ZHTAPOP3(350),    ZHTACH4(350),     ZHTANH4S(350),
     .              ZHTANO3S(350)
      DIMENSION AG3CFL(NSBP),     AG3NFL(NSBP),     AG3PFL(NSBP),
     .              APBSFL(NSBP),     ASDTMP(NSBP),     ASWTC(NSBP),
     .              APDIAG(NSBP),     APWC(NSBP),       ASALWC(NSBP),
     .              ADOWC(NSBP),      AKL12(NSBP),      AW12(NSBP)

***** Equivalence declarations

      EQUIVALENCE (KPDIAG(1),KPOP1),     (KPDIAG(2),KPOP2),
     .            (KPDIAG(3),KPOP3),     (KNDIAG(1),KPON1),
     .            (KNDIAG(2),KPON2),     (KNDIAG(3),KPON3),
     .            (KCDIAG(1),KPOC1),     (KCDIAG(2),KPOC2),
     .            (KCDIAG(3),KPOC3),     (DPTHTA(1),THTAPOP1),
     .            (DPTHTA(2),THTAPOP2),  (DPTHTA(3),THTAPOP3),
     .            (DNTHTA(1),THTAPON1),  (DNTHTA(2),THTAPON2),
     .            (DNTHTA(3),THTAPON3),  (DCTHTA(1),THTAPOC1),
     .            (DCTHTA(2),THTAPOC2),  (DCTHTA(3),THTAPOC3)

***** Common declarations

      COMMON /INPUTC/ M1,         M2,         DP,         W2,         DD,
     .                THTADP,     THTADD,     KAPPNH4,    PIENH4,     THTANH4,
     .                KMNH4,      KMNH4O2,    KAPP1NO3,   K2NO3,      THTANO3,
     .                KAPPD1,     KAPPP1,     PIE1S,      PIE2S,      THTAPD1,
     .                KMHSO2,     KSI,        CSISAT,     DPIE1SI,    PIE2SI,
     .                H2,         THTASI,     KMPSI,      DPIE1PO4,   PIE2PO4,
     .                O2CRIT,     KMO2DP,     TEMPBEN,
     .                KBENSTR,    KAPPCH4,    THTACH4,    KPDIAG,     DPTHTA,
     .                KNDIAG,     DNTHTA,     KCDIAG,     DCTHTA,     DPMIN,
     .                DPIE1PO4F,DPIE1PO4S,O2CRITSI,   JSIDETR,    KLBNTH
      COMMON /LOGSC1/ BENTHIC_OUTPUT,         STEADY_STATE_SED
      COMMON /SEDPOM/ PON1TM1S,   PON2TM1S,   PON3TM1S,   POC1TM1S,   POC2TM1S,
     .                POC3TM1S,   POP1TM1S,   POP2TM1S,   POP3TM1S,   PSITM1S,
     .                BENSTR1S,   BFORMAXS,   ISWBENS
      COMMON /CONCC1/ NH41TM1S,   NH4T2TM1S,NO31TM1S,   NO3T2TM1S,HS1TM1S,
     .                HST2TM1S,   SI1TM1S,    SIT2TM1S,   PO41TM1S,   PO4T2TM1S
      COMMON /CONCC2/ NH40,       NH41,       NH42,       NH4T1,      NH4T2,
     .                NH41TM1,    NH4T2TM1,   JNH4,       NO30,       NO31,
     .                NO32,       NO3T1,      NO3T2,      NO31TM1,    NO3T2TM1,
     .                JNO3,       HS0,        HS1,        HS2,        HST1,
     .                HST2,       HS1TM1,     HST2TM1,    JHS,        SI0,
     .                SI1,        SI2,        SIT1,       SIT2,       SI1TM1,
     .                SIT2TM1,    JSI,        PO40,       PO41,       PO42,
     .                PO4T1,      PO4T2,      PO41TM1,    PO4T2TM1,   JPO4,
     .                JCH4AQ,     JCH4G
      COMMON /DIAGC/  PON1,       PON1TM1,    PON2,       PON2TM1,    PON3,
     .                PON3TM1,    POC1,       POC1TM1,    POC2,       POC2TM1,
     .                POC3,       POC3TM1,    POP1,       POP1TM1,    POP2,
     .                POP2TM1,    POP3,       POP3TM1,    XJN,        XJC,
     .                XJP,        PSI,        PSITM1,     XJCNO3,     XJCO2,
     .                XJC1,       JO2NH4
      COMMON /NLPARS/ K0H1D,      K0H1P,      K1H1D,      K1H1P,      K2H2D,
     .                K2H2P,      K3,         PIE1,       PIE2,       J1,
     .                J2,         KMC1,       W12,        KL12,       TEMPD,
```

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     .                O20,      CH4SAT,   SAL
      COMMON /TSC/    SALTSW,   DLTS,     SALTND
      COMMON /STOREC/ XAPPNH4,  XAPPD1,   XAPPP1,   XAPP1NO3, XK2NO3,
     .                XKSI,     XAPPCH4,  TEMP20,   TEMP202,  FD1,
     .                FP1,      FD2,      FP2,      SOD,      CSOD,
     .                S,        W12NOM,   BENSTR,   BENSTRS,  BENSTR1,
     .                ISWBEN,   BFORMAX,  KL12NOM
      COMMON /THETAS/ ZHTADP,   ZHTADD,   ZHTANH4,  ZHTANO3,  ZHTA2NO3,
     .                ZHTAD1,   ZHTAP1,   ZHTASI,   ZL12NOM,  ZW12NOM,
     .                ZHTAPON1, ZHTAPON2, ZHTAPON3, ZHTAPOC1, ZHTAPOC2,
     .                ZHTAPOC3, ZHTAPOP1, ZHTAPOP2, ZHTAPOP3, ZHTACH4
      COMMON /MASSGC/ SEDMN,    SEDMP,    SEDMC,    ISEDMN,   ISEDMP,
     .                ISEDMC,   BURIALN,  BURIALP,  BURIALC,  DIAGENC,
     .                PSFLXN,   PSFLXP,   PSFLXC,   NPSFLXN,  NPSFLXP,
     .                NPSFLXC,  ATMFLXN,  ATMFLXP,  BENFLXPN, BENFLXPP,
     .                BENFLXPC, BENFLXDN, BENFLXDP, DLWCKMN,  DLWCKMC,
     .                BNDFLXN,  BNDFLXP,  BNDFLXC,  DLSEDKN,  DLSEDKC,
     .                CMASS,    IWCMN,    IWCMP,    IWCMC,    IWCMS,
     .                BURIALFLXN,  BURIALFLXP,  BURIALFLXC
      COMMON /MASSBC/ PSFLXNB,  PSFLXPB,  PSFLXCB,  NPSFLXNB, NPSFLXPB,
     .                NPSFLXCB, ATMFLXNB, ATMFLXPB, ATMFLXCB, BENFLXPNB,
     .                BENFLXDNB,BENFLXPPB,BENFLXDPB,BENFLXPCB,DLWCKMNB,
     .                DLWCKMCB, DLSEDKNB, DLSEDKCB, JDAYMBL,
     .                BURIALFLXNB, BURIALFLXPB, BURIALFLXCB
      COMMON /SEDINT/ TINTIM,   AG3CFL,   AG3NFL,   AG3PFL,   APBSFL,
     .                ASDTMP,   ASWTC,    APDIAG,   APWC,     ASALWC,
     .                ADOWC,    AKL12,    AW12
```

APPENDIX B

Control file for WQM: James River Estuary. February 1993

```
TITLE C ................................TITLE..................................
James River Estuary
Code without hard wires.
A sixty-eight box mock up of James River w/Appomattox and Chickahominy.
Steady-state hydrodynamics using the old HydroQual option.
Steady-state, summer-average conditions
November 27, 1992

GEOM DEFINE    NB      NSB      NQF     NHQF    NSHQF      NL
               68       16      149       97       16       5

TIME CON   TMSTRT    TMEND
              0.0     30.0

# DLT        NDLT
                1

DLT DAY      DLTD     DLTD     DLTD     DLTD     DLTD     DLTD     DLTD     DLTD     DLTD
              0.0

DLT VAL    DLTVAL   DLTVAL   DLTVAL   DLTVAL   DLTVAL   DLTVAL   DLTVAL   DLTVAL   DLTVAL
          10000.0

DLT MAX    DLTMAX   DLTMAX   DLTMAX   DLTMAX   DLTMAX   DLTMAX   DLTMAX   DLTMAX   DLTMAX
          10800.0

DLT FTN    DLTFTN   DLTFTN   DLTFTN   DLTFTN   DLTFTN   DLTFTN   DLTFTN   DLTFTN   DLTFTN
             0.95

HM DLT     AHMDLT    HMEND
              0.0    365.0

SNAPSHOT     SNPC     NSNP
               ON        1

SNAP DAY     SNPD     SNPD     SNPD     SNPD     SNPD     SNPD     SNPD     SNPD     SNPD
              0.0

SNAP FRQ     SNPF     SNPF     SNPF     SNPF     SNPF     SNPF     SNPF     SNPF     SNPF
             15.0

PLOT         PLTC    QPLTC    SPLTC     NPLT
               ON       ON       ON        1

PLOT DAY     PLTD     PLTD     PLTD     PLTD     PLTD     PLTD     PLTD     PLTD     PLTD
              0.0

PLOT FREQ    PLTF     PLTF     PLTF     PLTF     PLTF     PLTF     PLTF     PLTF     PLTF
             15.0

AV PLOT     APLTC     NAPL
               ON        1

AVPLT DAY   APLTD    APLTD    APLTD    APLTD    APLTD    APLTD    APLTD    APLTD    APLTD
               0.

AVPLT FREQ   APLF     APLF     APLF     APLF     APLF     APLF     APLF     APLF     APLF
             15.0

TRAN FLUX    TFLC     NTFL
               ON        1

FLUX DAY     TFLD     TFLD     TFLD     TFLD     TFLD     TFLD     TFLD     TFLD     TFLD
```

```
                  0.

FLUX FREQ      TFLF     TFLF     TFLF     TFLF     TFLF     TFLF     TFLF     TFLF     TFLF
               15.0

KIN FLUX       KFLC     NKFL     NKFLB   NKFLBB
                 ON        1        16      16

FLUX DAY       KFLD     KFLD     KFLD     KFLD     KFLD     KFLD     KFLD     KFLD     KFLD
                 0.

FLUX FREQ      KFLF     KFLF     KFLF     KFLF     KFLF     KFLF     KFLF     KFLF     KFLF
               15.0

WQM BOX        KFLB     KFLB     KFLB     KFLB     KFLB     KFLB     KFLB     KFLB     KFLB
                 28       29       37       38       39       40       41       42       43
                 48       58       59       60       64       65       68

SED BOX       KFLBB    KFLBB    KFLBB    KFLBB    KFLBB    KFLBB    KFLBB    KFLBB    KFLBB
                  1        2        3        4        5        6        7        8        9
                 10       11       12       13       14       15       16

OXY PLOT       OPLC     NOPL    NOINT
                OFF       12        8

OXY INT        OINT     OINT     OINT     OINT     OINT     OINT     OINT     OINT     OINT
               -1.0      1.0      2.0      3.0      4.0      5.0      8.0     16.0

OXY DAY        OPLD     OPLD     OPLD     OPLD     OPLD     OPLD     OPLD     OPLD     OPLD
                60.     150.     270.     365.     425.     515.     635.     730.     790.
               880.    1000.    1090.

OXY FREQ       OPLF     OPLF     OPLF     OPLF     OPLF     OPLF     OPLF     OPLF     OPLF
               200.     200.     200.     200.     200.     200.     200.     200.     200.
               200.     200.     200.     200.

MASS BAL       MBLC     NMBL
                 ON        1

MBL DAY        MBLD     MBLD     MBLD     MBLD     MBLD     MBLD     MBLD     MBLD     MBLD
                0.0

MBL FREQ       MBLF     MBLF     MBLF     MBLF     MBLF     MBLF     MBLF     MBLF     MBLF
               15.0

DIAGNSTCS      DIAC     NDIA
                 ON        1

DIA DAY        DIAD     DIAD     DIAD     DIAD     DIAD     DIAD     DIAD     DIAD     DIAD
                0.0

DIA FREQ       DIAF     DIAF     DIAF     DIAF     DIAF     DIAF     DIAF     DIAF     DIAF
               10.0

RESTART        RSOC     NRSO     RSIC
                OFF        1      OFF

RST DAY        RSOD     RSOD     RSOD     RSOD     RSOD     RSOD     RSOD     RSOD     RSOD
              364.0

HYD MODEL      HYDC
          HYDRO_QU

HYD SOLTN       SLC    CONSC       TH
             UPWIND     MASS      1.0
```

CONTROLS	SEDC	AUTOC	VBC	BFOC	STLC	ICIC			
	ON	ON	ON	OFF	ON	ON			
DEAD SEA	FLC	XYDFC	ZDFC						
	ON	ON	ON						
HDIFF	XYDF	ZDFMUL	ZDFMAX						
	10.0	1.0	0.1						
CST INPUT	BCC	PSC	NPSC	MDC	BFC	ATMC	SAVC		
	ON	ON	ON	ON	OFF	ON	OFF		
NUTR RED	REDPSC	REDPSN	REDPSP	REDNPC	REDNPN	REDNPP	REDCBC	REDCBN	REDCBP
	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0
BOUNDARY	ENDCC								
	FIXED								
BOUNDARY	BNDSC	BNDSC	BNDSC	BNDSC	BNDSC	BNDSC	BNDSC	BNDSC	BNDSC
	UPWIND	UPWIND	UPWIND	UPWIND	UPWIND	UPWIND	UPWIND	UPWIND	UPWIND
	UPWIND	UPWIND	UPWIND	UPWIND	UPWIND	UPWIND	UPWIND	UPWIND	UPWIND
	UPWIND	UPWIND	UPWIND	UPWIND					
ACT CST	ACC	ACC	ACC	ACC	ACC	ACC	ACC	ACC	ACC
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON	ON	ON	ON	ON	ON
	ON	ON	ON	ON					
HALF SAT 1	KHONT	KHNNT	KHNC	KHPC	KHRC	KHND	KHPD	KHRD	KHSD
	1.0	1.0	0.010	0.001	0.5	0.010	0.001	0.5	0.03
HALF SAT 2	KHNG	KHPG	KHRG	KHOCOD	KHODOC	KHNDN			
	0.010	0.001	0.5	0.5	0.5	0.1			
RATIOS	AOCR	AONT	ANCC	ANCD	ASCD	ANCG	ANDC		
	2.67	4.33	0.167	0.167	0.400	0.167	0.933		
P TO C	PCPRM1	PCPRM2	PCPRM3						
	42.0	85.0	200.0						
FRACTN N 1	FNIC	FNDC	FNLC	FNRC	FNID	FNDD	FNLD	FNRD	FNIG
	0.00	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
FRACTN N 2	FNDG	FNLG	FNRG	FNIP	FNDP	FNLP	FNRP		
	1.00	0.00	0.00	0.00	0.10	0.550	0.350		
FRACTN P 1	FPIC	FPDC	FPLC	FPRC	FPID	FPDD	FPLD	FPRD	FPIG
	0.00	1.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
FRACTN P 2	FPDG	FPLG	FPRG	FPIP	FPDP	FPLP	FPRP		
	1.00	0.00	0.00	0.20	0.50	0.200	0.100		
FRACTN C	FCDC	FCDD	FCDG	FDOP	FCDP	FCLP	FCRP		
	0.0	0.0	0.0	0.0	0.10	0.550	0.350		
MNRL/HYDRL	KDC	KLC	KRC	KND	KLN	KRN	KDP	KLP	KRP
	0.010	0.075	0.005	0.015	0.075	0.005	0.10	0.075	0.005
MNRL/HYDRL	KSUA	KCOD							
	0.03	20.0							
REF T RESP	TRC	TRD	TRG	TRCOD	TRMNL	TRHDR	TRSUA		
	20.0	20.0	20.0	23.0	20.0	20.0	20.0		
TEMP EFF	KTBC	KTBD	KTBG	KTCOD	KTMNL	KTHDR	KTSUA		
	0.069	0.069	0.069	0.041	0.069	0.069	0.092		

```
ALGAL EFF KDCALG   KLCALG   KRCALG   KDNALG   KLNALG   KRNALG   KDPALG   KLPALG   KRPALG
             0.0      0.0      0.0      0.0      0.0      0.0      0.2      0.0      0.0

SUBOPT T  KTNT1    KTGC1    KTGD1    KTGG1
            0.09    0.005    0.004    0.008

SUPOPT T  KTNT2    KTGC2    KTGD2    KTGG2
            0.09    0.004    0.006    0.010

MAX T       TMNT      TMC      TMD      TMG
            30.0     27.5     20.0     25.0

PREDATION   NPRD
              22

PRED DAY    PRDD     PRDD     PRDD     PRDD     PRDD     PRDD     PRDD     PRDD     PRDD
             0.0    152.0    365.0    517.0    730.0    882.0    1095.    1247.    1460.
           1612.    1825.    1977.    2190.    2342.    2555.    2707.    2920.    3072.
           3285.    3437.    3650.    3802.

PRED VAL  PRDVAL   PRDVAL   PRDVAL   PRDVAL   PRDVAL   PRDVAL   PRDVAL   PRDVAL   PRDVAL
             1.0      0.0      1.0      0.0      1.0      0.0      1.0      0.0      1.0
             1.0      0.0      1.0      0.0      1.0      0.0      1.0      0.0      1.0
             1.0      0.0      1.0      0.0      1.0      0.0      1.0      0.0      1.0

MACROBEN    MBGM       FR      UCM      UDM      UGM
             0.0      1.0      0.0      0.0      0.0

LIGHT 1    DOPTC    DOPTD    DOPTG    FCYAN    KECHL
             1.0      1.0      1.0      1.0     17.0

LIGHT 2       I0    ISMIN     I0WT     I1WT     I2WT
           110.0     40.0      0.7      0.2      0.1

METALS    KDOTAM   TAMDMX   BENTAM    KTBMF    KHBMF
             1.0    0.015     0.10      0.2      0.5

SORPTION  KADPO4    KADSA
             0.0      0.0

CAR/CHL    CCHLC    CCHLD    CCHLG
            60.0     60.0     60.0

MISC       NTMAX       DL        R     FSAP    SCTOX    AANOX
           0.070     14.9      0.4      0.0      1.0      0.5

# FILES    NHYDF    NTVDF
               1        1

MAP FILE..................................MAPFN...................................
        wqm_map.jmr

GEO FILE........... ......................GEOFN...................................
        wqm_geo.jmr

ICI FILE..................................ICIFN...................................
        wqm_ici.jmr

RSI FILE..................................RSIFN...................................
        wqm_rso.npt

AGR FILE..................................AGRFN...................................
        wqm_agr.jmr

STL FILE..................................STLFN...................................
```

wqm_stl.jmr

HYD FILE................................HYDFN...................................
wqm_hyd.jmr

MET FILE................................METFN...................................
wqm_met.jmr

PTS FILE................................PTSFN...................................
flloads.jmr

NPS FILE................................NPSFN...................................
bflloads.jmr

ATM FILE................................ATMFN...................................
wqm_atm.jmr

SAV FILE................................SAVFN...................................
wqm_sav.tv

EXT FILE................................EXTFN...................................
wqm_kei.jmr

CBC FILE................................CBCFN...................................
wqm_cbc.jmr

BFI FILE................................BFIFN...................................
wqm_bfi.jmr

SNP FILE................................SNPFN...................................
wqm_snp.opt

RSO FILE................................RSOFN...................................
wqm_rso.opt

PLT FILE................................PLTFN...................................
wqm_plt.opt

APL FILE................................APLFN...................................
wqm_apl.opt

DIA FILE................................DIAFN...................................
wqm_dia.opt

TFL FILE................................TFLFN...................................
wqm_tfl.opt

KFL FILE................................KFLFN...................................
wqm_kfl.opt

OPL FILE................................OPLFN...................................
wqm_opl.opt

MBL FILE................................MBLFN...................................
wqm_mbl.opt

BFO FILE................................BFOFN...................................
wqm_bfo.opt

APPENDIX C

James River Estuary w/ Appomattox and Chickahominy and 4m inflow
62-box, 149-face model
23 February 1993

F	QD	IL	IQ	JQ	JR
1	1	0	0	1	2
2	1	0	1	2	3
3	1	1	2	3	4
4	1	2	3	4	5
5	1	3	4	5	6
6	1	4	5	6	7
7	1	5	6	7	8
8	1	6	7	8	9
9	1	7	8	9	0
10	1	8	9	0	0
11	1	0	0	10	11
12	1	0	10	11	12
13	1	10	11	12	13
14	1	11	12	13	14
15	1	12	13	14	15
16	1	13	14	15	16
17	1	14	15	16	17
18	1	15	16	17	18
19	1	16	17	18	0
20	1	17	18	0	0
21	1	0	19	20	21
22	1	19	20	21	22
23	1	20	21	22	23
24	1	21	22	23	24
25	1	22	23	24	25
26	1	23	24	25	26
27	1	24	25	26	27
28	1	25	26	27	0
29	1	26	27	0	0
30	1	0	28	29	30
31	1	28	29	30	31
32	1	29	30	31	32
33	1	30	31	32	33
34	1	31	32	33	34
35	1	32	33	34	35
36	1	33	34	35	36
37	1	34	35	36	0
38	1	35	36	0	0
39	1	0	37	38	39
40	1	37	38	39	40
41	1	38	39	40	41
42	1	39	40	41	42
43	1	40	41	42	43
44	1	41	42	43	0
45	1	42	43	0	0
46	1	0	44	45	46
47	1	44	45	46	47
48	1	45	46	47	0
49	1	46	47	0	0
50	1	0	48	49	50
51	1	48	49	50	51
52	1	49	50	51	0
53	1	50	51	0	0
54	1	0	52	53	54
55	1	52	53	54	0
56	1	53	54	0	0
57	1	0	55	56	57
58	1	55	56	57	0

59	1	56	57	0	0
60	1	0	58	59	60
61	1	58	59	60	0
62	1	59	60	0	0
63	1	0	61	62	63
64	1	61	62	63	0
65	1	62	63	0	0
66	1	0	64	65	66
67	1	64	65	66	0
68	1	65	66	0	0
69	1	0	67	0	0
70	1	0	68	0	0
71	2	0	0	3	0
72	2	0	6	44	0
73	2	6	44	0	0
74	2	0	7	45	61
75	2	7	45	61	0
76	2	0	8	46	62
77	2	8	46	62	0
78	2	0	9	47	63
79	2	9	47	63	0
80	2	0	15	48	0
81	2	0	16	49	64
82	2	16	49	64	0
83	2	0	17	50	65
84	2	17	50	65	0
85	2	0	18	51	66
86	2	18	51	66	0
87	2	0	25	52	0
88	2	0	26	53	0
89	2	0	27	54	67
90	2	27	54	67	0
91	2	0	34	55	0
92	2	0	35	56	0
93	2	0	36	57	68
94	2	36	57	68	0
95	2	0	41	58	0
96	2	0	42	59	0
97	2	0	43	60	0
98	3	0	28	19	10
99	3	28	19	10	1
100	3	19	10	1	0
101	3	0	29	20	11
102	3	29	20	11	2
103	3	20	11	2	0
104	3	0	37	30	21
105	3	37	30	21	12
106	3	30	21	12	3
107	3	21	12	3	0
108	3	0	38	31	22
109	3	38	31	22	13
110	3	31	22	13	4
111	3	22	13	4	0
112	3	0	39	32	23
113	3	39	32	23	14
114	3	32	23	14	5
115	3	23	14	5	0
116	3	0	40	33	24
117	3	40	33	24	15
118	3	33	24	15	6
119	3	24	15	6	0
120	3	0	41	34	25
121	3	41	34	25	16
122	3	34	25	16	7
123	3	25	16	7	0
124	3	0	42	35	26

125	3	42	35	26	17
126	3	35	26	17	8
127	3	26	17	8	0
128	3	0	43	36	27
129	3	43	36	27	18
130	3	36	27	18	9
131	3	27	18	9	0
132	3	0	48	44	0
133	3	0	58	55	52
134	3	58	55	52	49
135	3	55	52	49	45
136	3	52	49	45	0
137	3	0	59	56	53
138	3	59	56	53	50
139	3	56	53	50	46
140	3	53	50	46	0
141	3	0	60	57	54
142	3	60	57	54	51
143	3	57	54	51	47
144	3	54	51	47	0
145	3	0	64	61	0
146	3	0	65	62	0
147	3	0	68	67	66
148	3	68	67	66	63
149	3	67	66	63	0

COLUMNS	NVF	NVF	NVF	NVF	NVF	NVF	NVF	NVF
1-9	3	3	4	4	4	4	4	4
	4	1	4	4	4	1	1	3

BBX	VFN	VFN	VFN	VFN	VFN	VFN	VFN	VFN	VFN
28	98	99	100						
29	101	102	103						
37	104	105	106	107					
38	108	109	110	111					
39	112	113	114	115					
40	116	117	118	119					
41	120	121	122	123					
42	124	125	126	127					
43	128	129	130	131					
48	132								
58	133	134	135	136					
59	137	138	139	140					
60	141	142	143	144					
64	145								
65	146								
68	147	148	149						

APPENDIX D

James River Estuary w/Appomattox and Chickahominy and 4m inflow
60-box, 149-face.
22 February 93

B	DLL(1)	DLL(2)	DLL(3)	VH	ZD
1	17500.0	1500.0	2.0	5.25E7	0.0
2	17500.0	1500.0	2.0	5.25E7	0.0
3	17500.0	1500.0	2.0	5.25E7	0.0
4	17500.0	1500.0	2.0	5.25E7	0.0
5	17500.0	1500.0	2.0	5.25E7	0.0
6	17500.0	1500.0	2.0	5.25E7	0.0
7	17500.0	1500.0	2.0	5.25E7	0.0
8	17500.0	1500.0	2.0	5.25E7	0.0
9	17500.0	1500.0	2.0	5.25E7	0.0
10	17500.0	1500.0	2.0	5.25E7	5.0
11	17500.0	1500.0	2.0	5.25E7	2.0
12	17500.0	1500.0	2.0	5.25E7	2.0
13	17500.0	1500.0	2.0	5.25E7	2.0
14	17500.0	1500.0	2.0	5.25E7	2.0
15	17500.0	1500.0	2.0	5.25E7	2.0
16	17500.0	1500.0	2.0	5.25E7	2.0
17	17500.0	1500.0	2.0	5.25E7	2.0
18	17500.0	1500.0	2.0	5.25E7	2.0
19	17500.0	1500.0	2.0	5.25E7	4.0
20	17500.0	1500.0	2.0	5.25E7	4.0
21	17500.0	1500.0	2.0	5.25E7	4.0
22	17500.0	1500.0	2.0	5.25E7	4.0
23	17500.0	1500.0	2.0	5.25E7	4.0
24	17500.0	1500.0	2.0	5.25E7	4.0
25	17500.0	1500.0	2.0	5.25E7	4.0
26	17500.0	1500.0	2.0	5.25E7	4.0
27	17500.0	1500.0	2.0	5.25E7	4.0
28	17500.0	1500.0	2.0	5.25E7	6.0
29	17500.0	1500.0	2.0	5.25E7	6.0
30	17500.0	1500.0	2.0	5.25E7	6.0
31	17500.0	1500.0	2.0	5.25E7	6.0
32	17500.0	1500.0	2.0	5.25E7	6.0
33	17500.0	1500.0	2.0	5.25E7	6.0
34	17500.0	1500.0	2.0	5.25E7	6.0
35	17500.0	1500.0	2.0	5.25E7	6.0
36	17500.0	1500.0	2.0	5.25E7	6.0
37	17500.0	1500.0	2.0	5.25E7	8.0
38	17500.0	1500.0	2.0	5.25E7	8.0
39	17500.0	1500.0	2.0	5.25E7	8.0
40	17500.0	1500.0	2.0	5.25E7	8.0
41	17500.0	1500.0	2.0	5.25E7	8.0
42	17500.0	1500.0	2.0	5.25E7	8.0
43	17500.0	1500.0	2.0	5.25E7	8.0
44	17500.0	1500.0	2.0	5.25E7	0.0
45	17500.0	1500.0	2.0	5.25E7	0.0
46	17500.0	1500.0	2.0	5.25E7	0.0
47	17500.0	1500.0	2.0	5.25E7	0.0
48	17500.0	1500.0	2.0	5.25E7	2.0
49	17500.0	1500.0	2.0	5.25E7	2.0
50	17500.0	1500.0	2.0	5.25E7	2.0
51	17500.0	1500.0	2.0	5.25E7	2.0
52	17500.0	1500.0	2.0	5.25E7	4.0
53	17500.0	1500.0	2.0	5.25E7	4.0
54	17500.0	1500.0	2.0	5.25E7	4.0
55	17500.0	1500.0	2.0	5.25E7	6.0
56	17500.0	1500.0	2.0	5.25E7	6.0
57	17500.0	1500.0	2.0	5.25E7	6.0
58	17500.0	1500.0	2.0	5.25E7	8.0
59	17500.0	1500.0	2.0	5.25E7	8.0
60	17500.0	1500.0	2.0	5.25E7	8.0
61	17500.0	1500.0	2.0	5.25E7	0.0
62	17500.0	1500.0	2.0	5.25E7	0.0

63	17500.0	1500.0	2.0	5.25E7	0.0
64	17500.0	1500.0	2.0	5.25E7	2.0
65	17500.0	1500.0	2.0	5.25E7	2.0
66	17500.0	1500.0	2.0	5.25E7	2.0
67	17500.0	1500.0	2.0	5.25E7	4.0
68	17500.0	1500.0	2.0	5.25E7	6.0

SB	BBX
1	28
2	29
3	37
4	38
5	39
6	40
7	41
8	42
9	43
44	48
45	58
46	59
47	60
61	64
62	65
63	68

APPENDIX E

James River Estuary w/ appomattox and Chickahominy and 4m inflow
February 23 1993

```
INIT CONC    CIC     CIC     CIC     CIC     CIC     CIC     CIC     CIC     CIC
            25.1    23.9     0.0     0.0     0.8    1.34     3.0     2.0    0.03
            0.02     0.2     0.5     0 2     1.0    0.05    0.06     0.5     1.0
             1.0     9.0     1.0     1.1

INIT SEDS  CTEMP
            20.0

           CPOP1   CPOP2   CPOP3
           1000.  10000.  75000.

           CPON1   CPON2   CPON3
          10000. 200000. 750000.

           CPOC1   CPOC2   CPOC3
          50000. 800000.    5.E6

            CPOS   PO4T2   NH4T2   NO3T2    HST2    SIT2   BENST
            5.E6  50000.   5000.     50.   2000.  75000.     20.

# MOD       NMOD    NMOD    NMOD    NMOD    NMOD    NMOD    NMOD    NMOD    NMOD
               0       0       0       0       0       0       0       0       0
               0       0       0       0       0       0       0       0       0
               0       0       0       0

       T    BMOD    BMOD    BMOD    BMOD    BMOD    BMOD    BMOD    BMOD    BMOD

            CMOD    CMOD    CMOD    CMOD    CMOD    CMOD    CMOD    CMOD    CMOD

    SALT    BMOD    BMOD    BMOD    BMOD    BMOD    BMOD    BMOD    BMOD    BMOD

            CMOD    CMOD    CMOD    CMOD    CMOD    CMOD    CMOD    CMOD    CMOD

     SSI    BMOD    BMOD    BMOD    BMOD    BMOD    BMOD    BMOD    BMOD    BMOD

            CMOD    CMOD    CMOD    CMOD    CMOD    CMOD    CMOD    CMOD    CMOD

      BC    BMOD    BMOD    BMOD    BMOD    BMOD    BMOD    BMOD    BMOD    BMOD

            CMOD    CMOD    CMOD    CMOD    CMOD    CMOD    CMOD    CMOD    CMOD

      BD    BMOD    BMOD    BMOD    BMOD    BMOD    BMOD    BMOD    BMOD    BMOD

            CMOD    CMOD    CMOD    CMOD    CMOD    CMOD    CMOD    CMOD    CMOD

      BG    BMOD    BMOD    BMOD    BMOD    BMOD    BMOD    BMOD    BMOD    BMOD

            CMOD    CMOD    CMOD    CMOD    CMOD    CMOD    CMOD    CMOD    CMOD

     DOC    BMOD    BMOD    BMOD    BMOD    BMOD    BMOD    BMOD    BMOD    BMOD
```

	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD
LPOC	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD
	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD
RPOC	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD
	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD
NH4	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD
	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD
NO3	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD
	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD
DON	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD
	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD
LPON	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD
	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD
RPON	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD
	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD
PO4	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD
	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD
DOP	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD
	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD
LPOP	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD
	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD
RPOP	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD

0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Diatoms

0.0003	0.0008	0.0015	0.0023	0.0034	0.0049	0.0076	0.0126	0.0370	0.0002
0.0008	0.0015	0.0023	0.0034	0.0049	0.0076	0.0126	0.0370	0.0002	0.0007
0.0016	0.0023	0.0036	0.0050	0.0072	0.0122	0.0339	0.0004	0.0008	0.0016
0.0023	0.0037	0.0058	0.0083	0.0135	0.0409	0.0018	0.0026	0.0036	0.0054
0.0081	0.0132	0.0402	0.0049	0.0076	0.0125	0.0390	0.0049	0.0076	0.0129
0.0380	0.0081	0.0131	0.0408	0.0076	0.0135	0.0398	0.0082	0.0122	0.0431
0.0079	0.0134	0.0421	0.0081	0.0132	0.0395	0.0397	0.0410		

Green algae

0.0395	0.0116	0.0042	0.0020	0.0019	0.0044	0.0127	0.0343	0.0838	0.1895
0.0261	0.0075	0.0027	0.0015	0.0024	0.0071	0.0216	0.0588	0.1438	0.3275
0.0202	0.0057	0.0021	0.0014	0.0027	0.0085	0.0263	0.0715	0.1729	0.3777
0.0395	0.0116	0.0042	0.0020	0.0019	0.0044	0.0127	0.0343	0.0838	0.1895
0.0261	0.0075	0.0027	0.0015	0.0024	0.0071	0.0216	0.0588	0.1438	0.3275
0.0202	0.0057	0.0021	0.0014	0.0027	0.0085	0.0263	0.0715	0.1729	0.3777
0.0261	0.0075	0.0027	0.0015	0.0024	0.0071	0.0216	0.0588		

Dissolved organic C

2.5561	2.0106	1.6811	1.5315	1.4962	1.4413	1.4043	1.3694	1.3458	2.2720
2.4035	1.8802	1.5971	1.4845	1.4549	1.4117	1.3773	1.3370	2.2862	2.1947
1.9301	1.8189	1.5583	1.4627	1.4361	1.3381	1.2043	2.6203	2.2581	2.1647
1.7561	1.6106	1.5811	1.4315	1.3962	1.2413	1.6843	1.5294	1.4858	1.4420
1.4035	1.3602	1.3371	1.4445	1.4149	1.3717	1.3473	1.4570	1.4062	1.3747
1.3301	1.4189	1.3683	1.3327	1.4361	1.3981	1.3443	1.4203	1.3781	1.3547
1.4521	1.3654	1.3325	1.4256	1.3631	1.3325	1.3256	1.3287		

Labile particulate C

0.0093	0.0109	0.0048	0.0035	0.0079	0.0075	0.0120	0.0223	0.0406	0.0531
0.0118	0.0107	0.0051	0.0045	0.0086	0.0108	0.0203	0.0384	0.0628	0.0705
0.0130	0.0105	0.0052	0.0050	0.0091	0.0131	0.0258	0.0488	0.0769	0.0820
0.0093	0.0109	0.0048	0.0035	0.0079	0.0075	0.0120	0.0223	0.0406	0.0531
0.0118	0.0107	0.0051	0.0045	0.0086	0.0108	0.0203	0.0384	0.0628	0.0705
0.0130	0.0105	0.0052	0.0050	0.0091	0.0131	0.0258	0.0488	0.0769	0.0820
0.0118	0.0107	0.0051	0.0045	0.0086	0.0108	0.0203	0.0384		

Refractory particulate C

0.2066	0.0650	0.0254	0.0134	0.0115	0.0110	0.0146	0.0223	0.0339	0.0418
0.2012	0.0626	0.0247	0.0139	0.0127	0.0145	0.0219	0.0350	0.0507	0.0534
0.1978	0.0611	0.0243	0.0143	0.0136	0.0169	0.0268	0.0434	0.0615	0.0611
0.2066	0.0650	0.0254	0.0134	0.0115	0.0110	0.0146	0.0223	0.0339	0.0418
0.2012	0.0626	0.0247	0.0139	0.0127	0.0145	0.0219	0.0350	0.0507	0.0534
0.1978	0.0611	0.0243	0.0143	0.0136	0.0169	0.0268	0.0434	0.0615	0.0611
0.2012	0.0626	0.0247	0.0139	0.0127	0.0145	0.0219	0.0350		

Ammonium

0.2704	0.3629	0.3841	0.3894	0.3925	0.3189	0.2679	0.0909	0.0264	0.2801
0.2801	0.3682	0.3866	0.3872	0.3766	0.2761	0.1581	0.0538	0.2853	0.2809
0.2831	0.3683	0.3851	0.3831	0.3283	0.1919	0.0818	0.2742	0.3606	0.3775
0.3904	0.3629	0.3241	0.2894	0.1925	0.0289	0.3179	0.2209	0.2764	0.3801
0.3801	0.3282	0.2366	0.3572	0.2766	0.1961	0.0281	0.3238	0.1753	0.1009
0.0531	0.2683	0.1851	0.0631	0.3363	0.2329	0.0718	0.2142	0.1506	0.0775
0.2142	0.1506	0.0775	0.2142	0.1506	0.0775	0.0856	0.0847		

Nitrate-nitrite

0.2430	0.1830	0.1295	0.1086	0.0859	0.0673	0.0421	0.0346	0.0266	0.312
0.1815	0.1529	0.1220	0.1023	0.0918	0.0674	0.0441	0.0267	0.2225	0.2108

	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD
COD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD
	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD
DO	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD
	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD
SU	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD
	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD
SA	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD	BMOD
	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD	CMOD

Temperature

25.9270	25.4710	25.7669	25.8596	25.8192	25.6848	25.4855	25.2670	25.1115	25.1482
25.9457	25.7019	25.0215	25.0740	25.9612	25.7321	25.4327	25.1511	23.0430	23.3396
24.4314	23.2814	23.6065	23.6363	24.4866	24.2106	24.8628	22.5518	21.4584	22.7769
22.9270	21.4710	22.7669	23.8596	22.8192	22.6848	21.4855	19.2670	19.1115	18.1482
18.9457	18.7019	19.0215	25.0740	25.9612	25.7321	25.4327	24.1511	24.0430	24.3396
24.4314	22.2814	23.6065	22.6363	20.4866	21.2106	21.8628	19.5518	19.4584	20.7769
25.1254	25.5896	25.4587	24.2485	24.5621	23.6958	21.5624	20.1254		

Salinity

1.0007	4.8823	7.5603	10.4101	13.2893	16.1070	17.8087	19.3684	23.9844	1.0908
4.8511	7.4289	10.4163	13.5474	16.6652	18.6744	20.5233	23.1947	1.7015	4.1140
7.9743	11.6971	13.8350	16.1021	17.3345	19.4346	23.3525	1.0733	4.6009	7.9156
11.6007	13.8823	16.5603	19.4101	22.2893	23.1070	8.8087	11.3684	13.7844	16.0908
19.8511	22.4289	24.4163	16.5474	17.6652	19.6744	23.5233	16.1947	18.7015	19.1140
22.9743	17.6971	19.8350	21.1021	17.3345	18.4346	20.3525	18.0733	20.6009	23.9156
17.2589	20.2145	23.9887	17.2102	18.5268	20.5687	22.5862	23.5210		

Iron + Manganese

0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		

Cyanobacteria

0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

0.2003	0.1954	0.1521	0.1385	0.1095	0.0875	0.0453	0.2279	0.2118	0.2022
0.1930	0.1530	0.1395	0.1086	0.0859	0.0473	0.2521	0.2046	0.1666	0.1382
0.1015	0.0829	0.0440	0.0623	0.0418	0.0374	0.0241	0.0967	0.0625	0.0408
0.0203	0.0954	0.0521	0.0385	0.0995	0.0675	0.0353	0.1079	0.0818	0.0422
0.0995	0.0675	0.0253	0.1079	0.0818	0.0222	0.0389	0.4128		

Dissolved organic N

0.1035	0.1116	0.1154	0.1243	0.1393	0.1517	0.1684	0.1894	0.2161	0.1024
0.1120	0.1105	0.1166	0.1278	0.1436	0.1693	0.1901	0.2258	0.1057	0.1156
0.1212	0.1301	0.1473	0.1595	0.1658	0.1831	0.2559	0.1039	0.1151	0.1151
0.1235	0.1416	0.1554	0.1883	0.2223	0.2717	0.1384	0.1594	0.1761	0.1818
0.2220	0.2405	0.2766	0.1878	0.2236	0.2593	0.2701	0.2058	0.2357	0.2656
0.2712	0.2101	0.2573	0.2695	0.2158	0.2531	0.2659	0.2139	0.2451	0.2751
0.2158	0.2531	0.2659	0.2139	0.2451	0.2751	0.2756	0.2745		

Labile particulate N

0.0015	0.0013	0.0006	0.0005	0.0009	0.0010	0.0019	0.0036	0.0064	0.0086
0.0019	0.0013	0.0007	0.0006	0.0010	0.0016	0.0033	0.0063	0.0101	0.0116
0.0021	0.0013	0.0007	0.0007	0.0012	0.0020	0.0042	0.0080	0.0125	0.0135
0.0015	0.0013	0.0006	0.0005	0.0009	0.0010	0.0019	0.0036	0.0064	0.0086
0.0019	0.0013	0.0007	0.0006	0.0010	0.0016	0.0033	0.0063	0.0101	0.0116
0.0021	0.0013	0.0007	0.0007	0.0012	0.0020	0.0042	0.0080	0.0125	0.0135
0.0015	0.0013	0.0006	0.0005	0.0009	0.0010	0.0019	0.0036		

Refractory particulate N

0.0177	0.0063	0.0028	0.0017	0.0018	0.0018	0.0024	0.0037	0.0057	0.0070
0.0175	0.0061	0.0028	0.0019	0.0020	0.0023	0.0036	0.0058	0.0084	0.0088
0.0173	0.0061	0.0028	0.0020	0.0021	0.0027	0.0044	0.0072	0.0102	0.0101
0.0177	0.0063	0.0028	0.0017	0.0018	0.0018	0.0024	0.0037	0.0057	0.0070
0.0175	0.0061	0.0028	0.0019	0.0020	0.0023	0.0036	0.0058	0.0084	0.0088
0.0173	0.0061	0.0028	0.0020	0.0021	0.0027	0.0044	0.0072	0.0102	0.0101
0.0063	0.0028	0.0017	0.0018	0.0018	0.0024	0.0037	0.0057		

Total phosphate

0.0238	0.0265	0.0233	0.0223	0.0247	0.0244	0.0249	0.0261	0.0289	0.0298
0.0240	0.0253	0.0224	0.0221	0.0241	0.0243	0.0254	0.0271	0.0294	0.0313
0.0240	0.0246	0.0219	0.0219	0.0237	0.0243	0.0256	0.0275	0.0297	0.0318
0.0238	0.0265	0.0233	0.0223	0.0247	0.0244	0.0249	0.0261	0.0289	0.0298
0.0240	0.0253	0.0224	0.0221	0.0241	0.0243	0.0254	0.0271	0.0294	0.0313
0.0240	0.0246	0.0219	0.0219	0.0237	0.0243	0.0256	0.0275	0.0297	0.0318
0.0253	0.0224	0.0221	0.0241	0.0243	0.0254	0.0271	0.0294		

Dissolved organic P

0.0041	0.0023	0.0013	0.0010	0.0011	0.0014	0.0021	0.0032	0.0050	0.0070
0.0034	0.0018	0.0011	0.0009	0.0011	0.0016	0.0026	0.0043	0.0065	0.0087
0.0031	0.0016	0.0009	0.0008	0.0011	0.0017	0.0029	0.0048	0.0072	0.0094
0.0041	0.0023	0.0013	0.0010	0.0011	0.0014	0.0021	0.0032	0.0050	0.0070
0.0034	0.0018	0.0011	0.0009	0.0011	0.0016	0.0026	0.0043	0.0065	0.0087
0.0031	0.0016	0.0009	0.0008	0.0011	0.0017	0.0029	0.0048	0.0072	0.0094
0.0018	0.0011	0.0009	0.0011	0.0016	0.0026	0.0043	0.0065		

Labile particulate P

0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0003	0.0006	0.0012
0.0001	0.0000	0.0000	0.0000	0.0001	0.0001	0.0003	0.0006	0.0012	0.0022
0.0001	0.0001	0.0000	0.0000	0.0001	0.0001	0.0003	0.0008	0.0015	0.0027
0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0003	0.0006	0.0012
0.0001	0.0000	0.0000	0.0000	0.0001	0.0001	0.0003	0.0006	0.0012	0.0022
0.0001	0.0001	0.0000	0.0000	0.0001	0.0001	0.0003	0.0008	0.0015	0.0027
0.0000	0.0000	0.0001	0.0001	0.0003	0.0008	0.0015	0.0027		

Refractory particulate P

0.0176	0.0057	0.0023	0.0013	0.0011	0.0009	0.0009	0.0010	0.0014	0.0018
0.0170	0.0054	0.0022	0.0013	0.0011	0.0010	0.0010	0.0013	0.0018	0.0026
0.0166	0.0052	0.0021	0.0013	0.0011	0.0010	0.0011	0.0015	0.0021	0.0030
0.0176	0.0057	0.0023	0.0013	0.0011	0.0009	0.0009	0.0010	0.0014	0.0018
0.0170	0.0054	0.0022	0.0013	0.0011	0.0010	0.0010	0.0013	0.0018	0.0026
0.0166	0.0052	0.0021	0.0013	0.0011	0.0010	0.0011	0.0015	0.0021	0.0030
0.0021	0.0013	0.0011	0.0010	0.0011	0.0015	0.0021	0.0030		

COD

0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		

Dissolved oxygen

11.5977	11.5961	11.3627	11.1493	10.9751	10.8459	10.7617	10.7204	10.7107	11.7175
11.9000	11.8226	11.5983	10.9084	10.7712	10.7045	10.5117	10.2952	11.4464	11.6657
11.4532	11.3424	10.3302	10.2575	10.2014	10.1936	10.1711	11.0189	11.2498	10.5701
10.5977	10.5961	10.3627	10.1493	9.9751	9.8459	10.5617	10.4204	10.3107	10.2175
10.1000	9.8226	9.7983	10.8084	10.4712	10.4945	10.3117	10.8052	10.4764	10.4957
10.3532	10.3424	10.1302	9.9575	10.8429	10.8136	9.8711	10.0189	9.5498	9.2701
10.8429	10.8136	9.8711	10.0189	9.5498	9.2701	9.7825	9.5687		

Particulate silica

0.0031	0.0062	0.0091	0.0116	0.0138	0.0160	0.0182	0.0202	0.0213	0.0199
0.0035	0.0069	0.0098	0.0124	0.0148	0.0171	0.0193	0.0211	0.0209	0.0158
0.0037	0.0072	0.0102	0.0128	0.0152	0.0175	0.0198	0.0214	0.0205	0.0144
0.0031	0.0062	0.0091	0.0116	0.0138	0.0160	0.0182	0.0202	0.0213	0.0199
0.0035	0.0069	0.0098	0.0124	0.0148	0.0171	0.0193	0.0211	0.0209	0.0158
0.0037	0.0072	0.0102	0.0128	0.0152	0.0175	0.0198	0.0214	0.0205	0.0144
0.0072	0.0102	0.0128	0.0152	0.0175	0.0198	0.0214	0.0205		

Dissolved silica

1.0041	1.9365	1.8190	1.6659	1.4877	1.2921	1.0855	1.8730	1.6585	1.4430
1.0038	1.9191	1.7800	1.6030	1.4001	1.1806	1.9517	1.7195	1.4885	1.2580
1.0058	1.9125	1.7629	1.5743	1.3596	1.1285	1.8890	1.6479	1.4116	1.1879
1.0041	1.9365	1.8190	1.6659	1.4877	1.2921	1.0855	1.8730	1.6585	1.4430
1.0038	1.9191	1.7800	1.6030	1.4001	1.1806	1.9517	1.7195	1.4885	1.2580
1.0058	1.9125	1.7629	1.5743	1.3596	1.1285	1.8890	1.6479	1.4116	1.1879
1.9365	1.8190	1.6659	1.4877	1.2921	1.0855	1.8730	1.6587		

Sediment Temperature

6.53E+0	7.40E+0	7.73E+0	7.76E+0	7.61E+0	7.33E+0	6.98E+0	6.65E+0	6.52E+0	6.81E+0
6.53E+0	7.40E+0	7.73E+0	7.76E+0	7.61E+0	7.33E+0				

G1 Sediment POP

1.45E+2	1.15E+2	1.01E+2	1.05E+2	1.27E+2	1.75E+2	2.96E+2	5.90E+2	1.27E+3	2.72E+3
1.45E+2	1.15E+2	1.01E+2	1.05E+2	1.27E+2	1.75E+2				

G1 Sediment PON

3.16E+3	2.73E+3	2.45E+3	2.47E+3	2.78E+3	3.17E+3	4.02E+3	5.56E+3	7.79E+3	9.36E+3
3.16E+3	2.73E+3	2.45E+3	2.47E+3	2.78E+3	3.17E+3				

G1 Sediment POC

1.90E+4 1.74E+4 1.50E+4 1.51E+4 1.75E+4 1.95E+4 2.48E+4 3.49E+4 5.06E+4 6.44E+4
1.90E+4 1.74E+4 1.50E+4 1.51E+4 1.75E+4 1.95E+4

G2 Sediment POP

6.51E+4 2.35E+4 1.23E+4 9.20E+3 8.85E+3 8.62E+3 1.01E+4 1.41E+4 2.28E+4 3.85E+4
6.51E+4 2.35E+4 1.23E+4 9.20E+3 8.85E+3 8.62E+3

G2 Sediment PON

2.53E+5 2.37E+5 2.11E+5 1.92E+5 1.80E+5 1.68E+5 1.59E+5 1.53E+5 1.45E+5 1.22E+5
2.53E+5 2.37E+5 2.11E+5 1.92E+5 1.80E+5 1.68E+5

G2 Sediment POC

1.69E+6 1.35E+6 1.15E+6 1.03E+6 9.61E+5 8.96E+5 8.50E+5 8.29E+5 8.13E+5 7.33E+5
1.69E+6 1.35E+6 1.15E+6 1.03E+6 9.61E+5 8.96E+5

G3 Sediment POP

4.57E+5 1.68E+5 8.57E+4 6.36E+4 6.21E+4 6.06E+4 6.99E+4 9.57E+4 1.50E+5 2.47E+5
4.57E+5 1.68E+5 8.57E+4 6.36E+4 6.21E+4 6.06E+4

G3 Sediment PON

9.13E+5 9.11E+5 8.39E+5 7.87E+5 7.54E+5 7.05E+5 6.61E+5 6.21E+5 5.72E+5 4.66E+5
9.13E+5 9.11E+5 8.39E+5 7.87E+5 7.54E+5 7.05E+5

G3 Sediment POC

1.07E+7 8.86E+6 7.77E+6 7.17E+6 6.82E+6 6.38E+6 6.00E+6 5.70E+6 5.40E+6 4.72E+6
1.07E+7 8.86E+6 7.77E+6 7.17E+6 6.82E+6 6.38E+6

Sediment PBS

2.20E+6 2.15E+6 2.12E+6 2.11E+6 2.09E+6 2.08E+6 2.07E+6 2.07E+6 2.07E+6 2.09E+6
2.20E+6 2.15E+6 2.12E+6 2.11E+6 2.09E+6 2.08E+6

Sediment PO4

1.88E+5 1.14E+5 8.81E+4 8.89E+4 1.08E+5 1.19E+5 1.27E+5 1.53E+5 2.09E+5 3.14E+5
1.88E+5 1.14E+5 8.81E+4 8.89E+4 1.08E+5 1.19E+5

Sediment NH4

6.08E+3 6.19E+3 5.69E+3 5.35E+3 5.23E+3 5.09E+3 5.11E+3 5.31E+3 5.59E+3 5.26E+3
6.08E+3 6.19E+3 5.69E+3 5.35E+3 5.23E+3 5.09E+3

Sediment NO3

8.19E+1 6.94E+1 5.65E+1 4.87E+1 4.40E+1 3.75E+1 3.27E+1 2.95E+1 2.65E+1 1.98E+1
8.19E+1 6.94E+1 5.65E+1 4.87E+1 4.40E+1 3.75E+1

Sediment HS

2.03E+3 1.80E+3 1.65E+3 1.54E+3 1.47E+3 1.40E+3 1.34E+3 1.31E+3 1.28E+3 1.21E+3
2.03E+3 1.80E+3 1.65E+3 1.54E+3 1.47E+3 1.40E+3

Sediment DSIL

7.05E+5 6.46E+5 5.98E+5 5.57E+5 5.17E+5 4.73E+5 4.29E+5 3.85E+5 3.40E+5 3.06E+5
7.05E+5 6.46E+5 5.98E+5 5.57E+5 5.17E+5 4.73E+5

Benthic Stress

1.25E+1 1.39E+1 1.39E+1 1.36E+1 1.33E+1 1.30E+1 1.26E+1 1.21E+1 1.17E+1 1.12E+1

1.25E+1 1.39E+1 1.39E+1 1.36E+1 1.33E+1 1.30E+1

APPENDIX F

James River Estuary w Appomattox and Chickahominy and 4m inflow
22 February 1993

BOX	PMC	BMRC	BPRC	PMD	BMRD	BPRD	PMG	BMRG	BPRG
1	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
2	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
3	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
4	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
5	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
6	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
7	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
8	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
9	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
10	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
11	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
12	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
13	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
14	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
15	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
16	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
17	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
18	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
19	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
20	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
21	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
22	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
23	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
24	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
25	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
26	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
27	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
28	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
29	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
30	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
31	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
32	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
33	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
34	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
35	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
36	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
37	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
38	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
39	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
40	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
41	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
42	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
43	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
44	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
45	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
46	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
47	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
48	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
49	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
50	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
51	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
52	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
53	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
54	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
55	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
56	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
57	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
58	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
59	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
60	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
61	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215
62	2.000	0.010	0.210	2.250	0.010	0.215	2.500	0.010	0.215

APPENDIX G

James River Estuary w/ Appomattox and Chickahominy and 4m inflow
February 23, 1993

BOX	WSS	WSLAB	WSREF	WSC	WSDB	WSDS	WSG
1	0.100	1.000	1.000	0.100	0.100	0.250	0.100
2	0.100	1.000	1.000	0.100	0.100	0.250	0.100
3	0.100	1.000	1.000	0.100	0.100	0.250	0.100
4	0.100	1.000	1.000	0.100	0.100	0.250	0.100
5	0.100	1.000	1.000	0.100	0.100	0.250	0.100
6	0.100	1.000	1.000	0.100	0.100	0.250	0.100
7	0.100	1.000	1.000	0.100	0.100	0.250	0.100
8	0.100	1.000	1.000	0.100	0.100	0.250	0.100
9	0.100	1.000	1.000	0.100	0.100	0.250	0.100
10	0.100	1.000	1.000	0.100	0.100	0.250	0.100
11	0.100	1.000	1.000	0.100	0.100	0.250	0.100
12	0.100	1.000	1.000	0.100	0.100	0.250	0.100
13	0.100	1.000	1.000	0.100	0.100	0.250	0.100
14	0.100	1.000	1.000	0.100	0.100	0.250	0.100
15	0.100	1.000	1.000	0.100	0.100	0.250	0.100
16	0.100	1.000	1.000	0.100	0.100	0.250	0.100
17	0.100	1.000	1.000	0.100	0.100	0.250	0.100
18	0.100	1.000	1.000	0.100	0.100	0.250	0.100
19	0.100	1.000	1.000	0.100	0.100	0.250	0.100
20	0.100	1.000	1.000	0.100	0.100	0.250	0.100
21	0.100	1.000	1.000	0.100	0.100	0.250	0.100
22	0.100	1.000	1.000	0.100	0.100	0.250	0.100
23	0.100	1.000	1.000	0.100	0.100	0.250	0.100
24	0.100	1.000	1.000	0.100	0.100	0.250	0.100
25	0.100	1.000	1.000	0.100	0.100	0.250	0.100
26	0.100	1.000	1.000	0.100	0.100	0.250	0.100
27	0.100	1.000	1.000	0.100	0.100	0.250	0.100
28	0.100	1.000	1.000	0.100	0.100	0.250	0.100
29	0.100	1.000	1.000	0.100	0.100	0.250	0.100
30	0.100	1.000	1.000	0.100	0.100	0.250	0.100
31	0.100	1.000	1.000	0.100	0.100	0.250	0.100
32	0.100	1.000	1.000	0.100	0.100	0.250	0.100
33	0.100	1.000	1.000	0.100	0.100	0.250	0.100
34	0.100	1.000	1.000	0.100	0.100	0.250	0.100
35	0.100	1.000	1.000	0.100	0.100	0.250	0.100
36	0.100	1.000	1.000	0.100	0.100	0.250	0.100
37	0.100	1.000	1.000	0.100	0.100	0.250	0.100
38	0.100	1.000	1.000	0.100	0.100	0.250	0.100
39	0.100	1.000	1.000	0.100	0.100	0.250	0.100
40	0.100	1.000	1.000	0.100	0.100	0.250	0.100
41	0.100	1.000	1.000	0.100	0.100	0.250	0.100
42	0.100	1.000	1.000	0.100	0.100	0.250	0.100
43	0.100	1.000	1.000	0.100	0.100	0.250	0.100
44	0.100	1.000	1.000	0.100	0.100	0.250	0.100
45	0.100	1.000	1.000	0.100	0.100	0.250	0.100
46	0.100	1.000	1.000	0.100	0.100	0.250	0.100
47	0.100	1.000	1.000	0.100	0.100	0.250	0.100
48	0.100	1.000	1.000	0.100	0.100	0.250	0.100
49	0.100	1.000	1.000	0.100	0.100	0.250	0.100
50	0.100	1.000	1.000	0.100	0.100	0.250	0.100
51	0.100	1.000	1.000	0.100	0.100	0.250	0.100
52	0.100	1.000	1.000	0.100	0.100	0.250	0.100
53	0.100	1.000	1.000	0.100	0.100	0.250	0.100
54	0.100	1.000	1.000	0.100	0.100	0.250	0.100
55	0.100	1.000	1.000	0.100	0.100	0.250	0.100
56	0.100	1.000	1.000	0.100	0.100	0.250	0.100
57	0.100	1.000	1.000	0.100	0.100	0.250	0.100
58	0.100	1.000	1.000	0.100	0.100	0.250	0.100
59	0.100	1.000	1.000	0.100	0.100	0.250	0.100
60	0.100	1.000	1.000	0.100	0.100	0.250	0.100
61	0.100	1.000	1.000	0.100	0.100	0.250	0.100
62	0.100	1.000	1.000	0.100	0.100	0.250	0.100

APPENDIX H

James River Estuary w/ Appomattox and Chickahominy and 4m inflow
February 22, 1993

JDAY	KT	TE	IO	FD
0.0	31.1	9.5	110.7	0.391
1.0	34.0	9.5	102.6	0.392
2.0	34.8	0.3	82.5	0.392
3.0	23.8	-0.4	82.9	0.393
4.0	40.1	0.9	183.7	0.393
5.0	17.0	1.9	209.7	0.394
6.0	23.8	2.2	100.0	0.394
7.0	36.5	0.1	179.4	0.395
8.0	28.0	-4.7	220.7	0.396
9.0	15.4	-5.3	97.3	0.396
10.0	22.9	-3.4	127.8	0.397
11.0	36.9	-4.1	230.8	0.398
12.0	28.2	-1.7	199.7	0.399
13.0	28.0	1.0	221.2	0.400
14.0	54.2	-3.7	230.8	0.401
15.0	25.5	-5.4	229.8	0.402
16.0	19.5	-2.0	91.3	0.402
17.0	12.5	-0.9	91.9	0.403
18.0	23.2	0.8	176.2	0.404
19.0	36.9	-11.1	210.5	0.405
20.0	27.2	-13.3	260.2	0.407
21.0	33.5	-6.1	240.1	0.408
22.0	18.0	-2.7	259.0	0.409
23.0	16.9	-1.2	183.3	0.410
24.0	29.4	1.2	229.6	0.411
25.0	49.0	-4.8	243.6	0.412
26.0	14.9	-3.9	167.3	0.413
27.0	13.7	-1.3	114.0	0.415
28.0	16.0	-0.3	275.5	0.416
29.0	15.0	-2.5	138.8	0.417
30.0	24.6	0.1	105.1	0.419
31.0	15.0	0.6	106.1	0.420
32.0	21.4	0.2	107.4	0.421
33.0	25.0	-2.7	213.5	0.423
34.0	14.1	-2.7	233.5	0.424
35.0	15.5	-2.7	120.9	0.425
36.0	11.4	0.3	124.9	0.427
37.0	33.0	-1.1	251.3	0.428
38.0	59.2	-6.0	320.9	0.430
39.0	51.8	-4.3	324.6	0.431
40.0	28.3	-1.7	316.3	0.433
41.0	12.5	1.9	270.3	0.434
42.0	49.6	3.3	133.1	0.436
43.0	30.8	-0.1	196.3	0.437
44.0	23.9	0.0	187.2	0.439
45.0	14.7	1.3	314.3	0.440
46.0	18.1	0.0	309.0	0.442
47.0	19.0	2.8	284.5	0.443
48.0	25.3	2.7	346.5	0.445
49.0	25.9	3.9	185.2	0.447
50.0	15.8	3.9	314.9	0.448
51.0	18.5	3.1	253.4	0.450
52.0	37.0	9.6	166.9	0.452
53.0	41.3	12.4	187.9	0.453
54.0	63.6	14.9	175.5	0.455
55.0	36.9	9.8	157.7	0.457
56.0	18.2	6.3	139.4	0.458
57.0	38.0	7.4	194.8	0.460
58.0	26.2	2.7	402.9	0.462
59.0	26.4	5.1	274.4	0.463
60.0	23.5	10.3	404.5	0.465
61.0	25.4	5.4	325.9	0.467

APPENDIX J

Fall-line load for James River Estuary w/ Appomattox and Chickahominy
November 12, 1992

	NPSLN	NPSLN	NPSLN	NPSLN	NPSLN	NPSLN	NPSLN	NPSLN	NPSLN
	0	0	1	0	0	0	1	1	1
	1	1	1	1	1	1	1	1	1
	0	0	0	0					
TEMP	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
SALT	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
FEMN	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
	1								
CYAN	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
DIAT	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
GREN	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
DOC	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
	1								
LPOC	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
	1								
RPOC	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
	1								
NH4	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
	1								
NO3	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
	1								
DON	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
	1								
LPON	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
	1								
RPON	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
	1								
PO4	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
	1								
DOP	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
	1								
LPOP	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
	1								
RPOP	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
	1								
COD	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
DO	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB

	PSIL	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
	DSIL	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
NPS LOAD		JDAY	KG/DAY	KG/DAY	KG/DAY	KG/DAY	KG/DAY	KG/DAY	KG/DAY	KG/DAY
	TEMP	0.0	0.0							
	SALT	0.0	0.0							
	FEMN	0.0	356.0							
	CYAN	0.0	0.0							
	DIAT	0.0	0.0							
	GREN	0.0	0.0							
	DOC	0.0	648000.0							
	LPOC	0.0	1.0							
	RPOC	0.0	162000.0							
	NH4	0.0	33000.0							
	NO3	0.0	264000.0							
	DON	0.0	19800.0							
	LPON	0.0	1.0							
	RPON	0.0	13200.0							
	PO4	0.0	3900.0							
	DOP	0.0	1560.0							
	LPOP	0.0	1.0							
	RPOP	0.0	14040.0							
	COD	0.0	0.0							
	DO	0.0	0.0							
	PSIL	0.0	0.0							
	DSIL	0.0	0.0							
	TEMP	10.0	0.0							
	SALT	10.0	0.0							
	FEMN	10.0	453.0							
	CYAN	10.0	0.0							
	DIAT	10.0	0.0							
	GREN	10.0	0.0							
	DOC	10.0	648000.0							
	LPOC	10.0	1.0							
	RPOC	10.0	162000.0							
	NH4	10.0	33000.0							
	NO3	10.0	264000.0							
	DON	10.0	19800.0							
	LPON	10.0	1.0							
	RPON	10.0	13200.0							
	PO4	10.0	3900.0							
	DOP	10.0	1560.0							
	LPOP	10.0	1.0							
	RPOP	10.0	14040.0							
	COD	10.0	0.0							
	DO	10.0	0.0							
	PSIL	10.0	0.0							
	DSIL	10.0	0.0							
	TEMP	20.0	0.0							
	SALT	20.0	0.0							
	FEMN	20.0	12.0							
	CYAN	20.0	0.0							
	DIAT	20.0	0.0							
	GREN	20.0	0.0							
	DOC	20.0	648000.0							
	LPOC	20.0	1.0							
	RPOC	20.0	162000.0							
	NH4	20.0	33000.0							
	NO3	20.0	264000.0							
	DON	20.0	19800.0							
	LPON	20.0	1.0							

APPENDIX K

Below-fall-line loads for James River Estuary w/ Appomattox and Chickahominy
February 13 1993

	NPSLN	NPSLN	NPSLN	NPSLN	NPSLN	NPSLN	NPSLN	NPSLN	NPSLN
	0	0	13	0	0	0	13	13	13
	13	13	13	13	13	13	13	13	13
	0	0	0	0					
TEMP	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
SALT	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
FEMN	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
	1	2	3	4	5	6	7	8	9
	44	61	62	63					
CYAN	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
DIAT	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
GREN	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
DOC	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
	1	2	3	4	5	6	7	8	9
	44	61	62	63					
LPOC	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
	1	2	3	4	5	6	7	8	9
	44	61	62	63					
RPOC	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
	1	2	3	4	5	6	7	8	9
	44	61	62	63					
NH4	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
	1	2	3	4	5	6	7	8	9
	44	61	62	63					
NO3	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
	1	2	3	4	5	6	7	8	9
	44	61	62	63					
DON	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
	1	2	3	4	5	6	7	8	9
	44	61	62	63					
LPON	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
	1	2	3	4	5	6	7	8	9
	44	61	62	63					
RPON	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
	1	2	3	4	5	6	7	8	9
	44	61	62	63					
PO4	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
	1	2	3	4	5	6	7	8	9
	44	61	62	63					
DOP	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
	1	2	3	4	5	6	7	8	9
	44	61	62	63					

LPOP	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
	1	2	3	4	5	6	7	8	9
	44	61	62	63					
RPOP	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
	1	2	3	4	5	6	7	8	9
	44	61	62	63					
COD	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
DO	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
PSIL	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
DSIL	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB	NPSLB
NPS LOAD	JDAY	KG/DAY	KG/DAY	KG/DAY	KG/DAY	KG/DAY	KG/DAY	KG/DAY	KG/DAY
TEMP	0.0	0.0							
SALT	0.0	0.0							
FEMN	0.0	318.0	318.0	318.0	318.0	318.0	318.0	318.0	318.0
		318.0	318.0	429.6	429.6	429.6			
CYAN	0.0	0.0							
DIAT	0.0	0.0							
GREN	0.0	0.0							
DOC	0.0	6960.0	6960.0	6960.0	6960.0	6960.0	6960.0	6960.0	6960.0
		6960.0	6960.0	33300.0	33300.0	33300.0			
LPOC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	6243.8	6243.8	6243.8			
RPOC	0.0	1740.0	1740.0	1740.0	1740.0	1740.0	1740.0	1740.0	1740.0
		1740.0	1740.0	2081.2	2081.2	2081.2			
NH4	0.0	795.0	795.0	795.0	795.0	795.0	795.0	795.0	795.0
		795.0	795.0	14319.0	14319.0	14319.0			
NO3	0.0	6360.0	6360.0	6360.0	6360.0	6360.0	6360.0	6360.0	6360.0
		6360.0	6360.0	10023.3	10023.3	10023.3			
DON	0.0	477.0	477.0	477.0	477.0	477.0	477.0	477.0	477.0
		477.0	477.0	436.6	436.6	436.6			
LPON	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	429.6	429.6	429.6			
RPON	0.0	318.0	318.0	318.0	318.0	318.0	318.0	318.0	318.0
		318.0	318.0	429.6	429.6	429.6			
PO4	0.0	114.0	114.0	114.0	114.0	114.0	114.0	114.0	114.0
		114.0	114.0	2066.3	2066.3	2066.3			
DOP	0.0	45.6	45.6	45.6	45.6	45.6	45.6	45.6	45.6
		45.6	45.6	145.9	145.9	145.9			
LPOP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0			
RPOP	0.0	410.4	410.4	410.4	410.4	410.4	410.4	410.4	410.4
		410.4	410.4	218.8	218.8	218.8			
COD	0.0	0.0							
DO	0.0	0.0							
PSIL	0.0	0.0							
DSIL	0.0	0.0							
TEMP	10.0	0.0							
SALT	10.0	0.0							
FEMN	10.0	318.0	318.0	318.0	318.0	318.0	318.0	318.0	318.0
		318.0	318.0	429.6	429.6	429.6			
CYAN	10.0	0.0							
DIAT	10.0	0.0							
GREN	10.0	0.0							
DOC	10.0	6960.0	6960.0	6960.0	6960.0	6960.0	6960.0	6960.0	6960.0
		6960.0	6960.0	33300.0	33300.0	33300.0			

APPENDIX L

James River Estuary /w Appomattox and Chickahominy and 4m inflow
February 22, 1993

JDAY	RNFL	NH4	NO3	DON	PO4	DOP
0.0	0.24	0.18	0.65	0.21	0.016	0.022
61.0	0.28	0.18	0.65	1.25	0.015	0.065
152.0	0.33	0.18	0.65	0.74	0.014	0.065
243.0	0.26	0.18	0.65	0.39	0.021	0.029
335.0	0.24	0.18	0.65	0.21	0.016	0.022
364.0	0.24	0.18	0.65	0.21	0.016	0.022

APPENDIX M

James River Estuary w/ Appomattox and Chickahominy and 4m inflow
February 24, 1993

DAY	KE	KE	KE	KE	KE	KE	KE	KE	KE
0.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	1.0	1.0	1.0	1.0	1.0				
1100.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	1.0	1.0	1.0	1.0	1.0				

APPENDIX N

James River Estuary w/ Appomattox and Chickahominy and 4m inflow
February 23, 1993

	NBC	NBC	NBC	NBC	NBC	NBC	NBC	NBC	NBC
	18	18	18	18	18	18	18	18	18
	18	18	18	18	18	18	18	18	18
	18	18	18	18					
	JDAY	BCOND	BCOND	BCOND	BCOND	BCOND	BCOND	BCOND	BCOND
TEMP	0.00	25.000	25.500	25.000	25.500	23.000	23.500	22.500	22.500
		22.000	25.500	25.000	23.000	22.000	22.000	25.500	25.000
		23.000	22.250						
ALPHA	0.00	0.000							
SALT	0.00	0.000	29.800	0.000	29.800	29.000	29.800	29.000	29.800
		29.800	29.800	29.800	29.800	29.800	29.800	29.800	29.800
		9.800	19.800						
ALPHA	0.00	0.000							
TAM	0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.000	0.000						
ALPHA	0.00	0.000							
CYAN	0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.000	0.000						
ALPHA	0.00	0.000							
DIAT	0.00	0.000	0.037	0.000	0.037	0.037	0.037	0.037	0.037
		0.037	0.037	0.037	0.037	0.037	0.037	0.037	0.037
		0.000	0.037						
ALPHA	0.00	0.000							
GREEN	0.00	0.180	0.745	0.180	0.745	0.745	0.745	0.745	0.745
		0.745	0.745	0.745	0.745	0.745	0.745	0.745	0.745
		0.185	0.745						
ALPHA	0.00	0.000							
DOC	0.00	2.000	1.070	2.000	1.070	1.000	1.070	1.000	1.070
		1.070	1.070	1.070	1.070	1.070	1.070	1.070	1.070
		1.070	1.070						
ALPHA	0.00	0.000							
LPOC	0.00	0.000	0.001	0.000	0.001	0.000	0.001	0.000	0.001
		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
		0.001	0.001						
ALPHA	0.00	0.000							
RPOC	0.00	0.200	0.030	0.200	0.030	0.200	0.030	0.200	0.030
		0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030
		0.030	0.030						
ALPHA	0.00	0.000							
NH4	0.00	0.200	0.021	0.200	0.021	0.200	0.021	0.020	0.021
		0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021
		0.021	0.021						
ALPHA	0.00	0.000							
NO3	0.00	0.200	0.021	0.200	0.021	0.200	0.021	0.200	0.021
		0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021
		0.021	0.021						
ALPHA	0.00	0.000							
DON	0.00	0.000	0.300	0.000	0.300	0.000	0.300	0.000	0.300
		0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300
		0.300	0.300						
ALPHA	0.00	0.000							
LPON	0.00	0.000	0.064	0.000	0.064	0.000	0.064	0.000	0.064
		0.025	0.050	0.071	0.013	0.011	0.070	0.021	0.040
		0.064	0.064						
ALPHA	0.00	0.000							
RPON	0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.000	0.000						
ALPHA	0.00	0.000							
PO4	0.00	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023

APPENDIX P

James River Estuary w/ Appomattox and Chickahominy and 4m inflow
February 24, 1993

FACE #	A
1	3.0E3
2	3.0E3
3	3.0E3
4	3.0E3
5	3.0E3
6	3.0E3
7	3.0E3
8	3.0E3
9	3.0E3
10	3.0E3
11	3.0E3
12	3.0E3
13	3.0E3
14	3.0E3
15	3.0E3
16	3.0E3
17	3.0E3
18	3.0E3
19	3.0E3
20	3.0E3
21	3.0E3
22	3.0E3
23	3.0E3
24	3.0E3
25	3.0E3
26	3.0E3
27	3.0E3
28	3.0E3
29	3.0E3
30	3.0E3
31	3.0E3
32	3.0E3
33	3.0E3
34	3.0E3
35	3.0E3
36	3.0E3
37	3.0E3
38	3.0E3
39	3.0E3
40	3.0E3
41	3.0E3
42	3.0E3
43	3.0E3
44	3.0E3
45	3.0E3
46	3.0E3
47	3.0E3
48	3.0E3
49	3.0E3
50	3.0E3
51	3.0E3
52	3.0E3
53	3.0E3
54	3.0E3
55	3.0E3
56	3.0E3
57	3.0E3
58	3.0E3
59	3.0E3
60	3.0E3
61	3.0E3
62	3.0E3

63	3.0E3
64	3.0E3
65	3.0E3
66	3.0E3
67	3.0E3
68	3.0E3
69	3.0E3
70	3.0E3
71	3.5E4
72	3.5E4
73	3.5E4
74	3.5E4
75	3.5E4
76	3.5E4
77	3.5E4
78	3.5E4
79	3.5E4
80	3.5E4
81	3.5E4
82	3.5E4
83	3.5E4
84	3.5E4
85	3.5E4
86	3.5E4
87	3.5E4
88	3.5E4
89	3.5E4
90	3.5E4
91	3.5E4
92	3.5E4
93	3.5E4
94	3.5E4
95	3.5E4
96	3.5E4
97	3.5E4
98	2.6E7
99	2.6E7
100	2.6E7
101	2.6E7
102	2.6E7
103	2.6E7
104	2.6E7
105	2.6E7
106	2.6E7
107	2.6E7
108	2.6E7
109	2.6E7
110	2.6E7
111	2.6E7
112	2.6E7
113	2.6E7
114	2.6E7
115	2.6E7
116	2.6E7
117	2.6E7
118	2.6E7
119	2.6E7
120	2.6E7
121	2.6E7
122	2.6E7
123	2.6E7
124	2.6E7
125	2.6E7
126	2.6E7
127	2.6E7
128	2.6E7

129	2.6E7
130	2.6E7
131	2.6E7
132	2.6E7
133	2.6E7
134	2.6E7
135	2.6E7
136	2.6E7
137	2.6E7
138	2.6E7
139	2.6E7
140	2.6E7
141	2.6E7
142	2.6E7
143	2.6E7
144	2.6E7
145	2.6E7
146	2.6E7
147	2.6E7
148	2.6E7
149	2.6E7

JDAY	FACE #	Q	DIFF
0.0	1	1774.	10.0
0.0	2	2000.	10.0
0.0	3	3000.	10.0
0.0	4	4000.	10.0
0.0	5	5000.	10.0
0.0	6	6000.	10.0
0.0	7	7000.	10.0
0.0	8	8000.	10.0
0.0	9	9000.	10.0
0.0	10	10000.	10.0
0.0	11	1774.	10.0
0.0	12	2000.	10.0
0.0	13	3000.	10.0
0.0	14	4000.	10.0
0.0	15	5000.	10.0
0.0	16	6000.	10.0
0.0	17	7000.	10.0
0.0	18	8000.	10.0
0.0	19	9000.	10.0
0.0	20	10000.	10.0
0.0	21	-1000.	10.0
0.0	22	-1000.	10.0
0.0	23	-2000.	10.0
0.0	24	-2500.	10.0
0.0	25	-3000.	10.0
0.0	26	-3500.	10.0
0.0	27	-4000.	10.0
0.0	28	-4500.	10.0
0.0	29	-5000.	10.0
0.0	30	-1000	10.0
0.0	31	-1000.	10.0
0.0	32	-2000.	10.0
0.0	33	-2500.	10.0
0.0	34	-3000.	10.0
0.0	35	-3500.	10.0
0.0	36	-4000.	10.0
0.0	37	-4500.	10.0
0.0	38	-4500.	10.0
0.0	39	-2000.	10.0
0.0	40	-2500.	10.0
0.0	41	-3000.	10.0
0.0	42	-3500.	10.0
0.0	43	-4000.	10.0

0.0	44	-4500.	10.0
0.0	45	-5000.	10.0
0.0	46	3000.	10.0
0.0	47	3300.	10.0
0.0	48	3500.	10.0
0.0	49	4000.	10.0
0.0	50	3000.	10.0
0.0	51	3000.	10.0
0.0	52	3500.	10.0
0.0	53	4000.	10.0
0.0	54	-500.	10.0
0.0	55	-900.	10.0
0.0	56	-1000.	10.0
0.0	57	-500.	10.0
0.0	58	-900.	10.0
0.0	59	-1000.	10.0
0.0	60	-500.	10.0
0.0	61	-900.	10.0
0.0	62	-1000.	10.0
0.0	63	500.	10.0
0.0	64	1500.	10.0
0.0	65	5000.	10.0
0.0	66	500.	10.0
0.0	67	1500.	10.0
0.0	68	5000.	10.0
0.0	69	-9000.	10.0
0.0	70	-9000.	10.0
0.0	71	1500.	1.0
0.0	72	-1000.	1.0
0.0	73	500.	1.0
0.0	74	500.	1.0
0.0	75	500.	1.0
0.0	76	500.	1.0
0.0	77	500.	1.0
0.0	78	500.	1.0
0.0	79	500.	1.0
0.0	80	500.	1.0
0.0	81	500.	1.0
0.0	82	500.	1.0
0.0	83	500.	1.0
0.0	84	500.	1.0
0.0	85	500.	1.0
0.0	86	500.	1.0
0.0	87	500.	1.0
0.0	88	-500.	1.0
0.0	89	-500.	1.0
0.0	90	-500.	1.0
0.0	91	-500.	1.0
0.0	92	-500.	1.0
0.0	93	-500.	1.0
0.0	94	-500.	1.0
0.0	95	-500.	1.0
0.0	96	-500.	1.0
0.0	97	-500.	1.0
0.0	98	500.	0.01
0.0	99	500.	0.01
0.0	100	500.	0.01
0.0	101	500.	0.01
0.0	102	500.	0.01
0.0	103	500.	0.01
0.0	104	500.	0.01
0.0	105	500.	0.01
0.0	106	500.	0.01
0.0	107	500.	0.01
0.0	108	500.	0.01
0.0	109	500.	0.01

0.0	110	500.	0.01
0.0	111	500.	0.01
0.0	112	500.	0.01
0.0	113	500	0.01
0.0	114	500.	0.01
0.0	115	500.	0.01
0.0	116	500.	0.01
0.0	117	500.	0.01
0.0	118	500.	0.01
0.0	119	500.	0.01
0.0	120	500.	0.01
0.0	121	500.	0.01
0.0	122	500.	0.01
0.0	123	500.	0.01
0.0	124	500.	0.01
0.0	125	500.	0.01
0.0	126	500.	0.01
0.0	127	500.	0.01
0.0	128	500.	0.01
0.0	129	500.	0.01
0.0	130	500.	0.01
0.0	131	500.	0.01
0.0	132	500.	0.01
0.0	133	500.	0.01
0.0	134	500.	0.01
0.0	135	500.	0.01
0.0	136	500.	0.01
0.0	137	500.	0.01
0.0	138	500.	0.01
0.0	139	500.	0.01
0.0	140	500.	0.01
0.0	141	500.	0.01
0.0	142	500.	0.01
0.0	143	500.	0.01
0.0	144	500.	0.01
0.0	145	500.	0.01
0.0	146	500.	0.01
0.0	147	500.	0.01
0.0	148	500.	0.01
0.0	149	500.	0.01
5000.0	1	1000.	10.0
5000.0	2	2000.	10.0
5000.0	3	3000.	10.0
5000.0	4	4000.	10.0
5000.0	5	5000.	10.0
5000.0	6	6000.	10.0
5000.0	7	7000.	10.0
5000.0	8	8000.	10.0
5000.0	9	9000.	10.0
5000.0	10	10000.	10.0
5000.0	11	1000.	10.0
5000.0	12	2000.	10.0
5000.0	13	3000.	10.0
5000.0	14	4000.	10.0
5000.0	15	5000.	10.0
5000.0	16	6000.	10.0
5000.0	17	7000.	10.0
5000.0	18	8000.	10.0
5000.0	19	9000.	10.0
5000.0	20	10000.	10.0
5000.0	21	-500.	10.0
5000.0	22	-1000.	10.0
5000.0	23	-1500.	10.0
5000.0	24	-2000.	10.0
5000.0	25	-2500.	10.0
5000.0	26	-3000.	10.0